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Advanced Propagation Model (APM) Version 2.1.04 Computer Software Configuration Item (CSCI) Documents

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PREFACE

This document provides Version 2.1.04 Computer Software Configuration Item documents for the Advanced Propagation Model (APM). The APM calculates range-dependent electromagnetic system propagation loss and propagation factor within a heterogeneous atmospheric medium over variable terrain, where the radio-frequency index of refraction is allowed to vary vertically and horizontally.

The first document specifies the functional requirements that are to be met by the APM CSCI. A discussion of the input software requirements is presented together with a general description of the internal structure of the APM CSCI as it relates to the CSCI's capability.

The second document describes the design of the APM CSCI. An overview of the input software requirements is presented together with an overview of the CSCI design architecture and a detailed design description of each CSCI component.

The third document specifies the test cases and test procedures necessary to perform APM CSCI qualification testing. A discussion of precise input values of each input variable required to perform the test together with final expected test results is presented.

SOFTWARE REQUIREMENTS SPECIFICATION
FOR THE
ADVANCED PROPAGATION MODEL CSCI
(Version 2.1.04)

20 December 2006

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1. SCOPE

1.1 IDENTIFICATION

The Advanced Propagation Model (APM) Version 2.1.04 computer software configuration item (CSCI) calculates range-dependent electromagnetic (EM) system propagation loss within a heterogeneous atmospheric medium over variable terrain, where the radio-frequency index of refraction is allowed to vary vertically and horizontally, also accounting for terrain effects along the path of propagation.

1.2 SYSTEM OVERVIEW

The APM CSCI model calculates propagation loss values as EM energy propagates through a laterally heterogeneous atmospheric medium where the index of refraction is allowed to vary vertically and horizontally, also accounting for terrain effects along the propagation path. Numerous external applications require EM-system propagation loss values. The APM model described by this document may be applied to two external applications, one that displays propagation loss on a range versus height scale (commonly referred to as a coverage diagram) and one that displays propagation loss on a propagation loss versus range/height scale (commonly referred to as a loss diagram).

1.3 DOCUMENT OVERVIEW

This document specifies the functional requirements that are to be met by the APM CSCI. A discussion of the input software requirements is presented together with a general description of the internal structure of the APM CSCI as it relates to the CSCI's capability.

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3. REQUIREMENTS

3.1 CSCI CAPABILITY REQUIREMENTS

The required APM CSCI propagation model is a range-dependent true hybrid model that uses the complimentary strengths of Ray Optics (RO) and Parabolic Equation (PE) techniques to calculate propagation loss both in range and altitude.

The atmospheric volume is divided into regions that lend themselves to the application of the various propagation loss calculation methods. Figure 1 illustrates these regions.

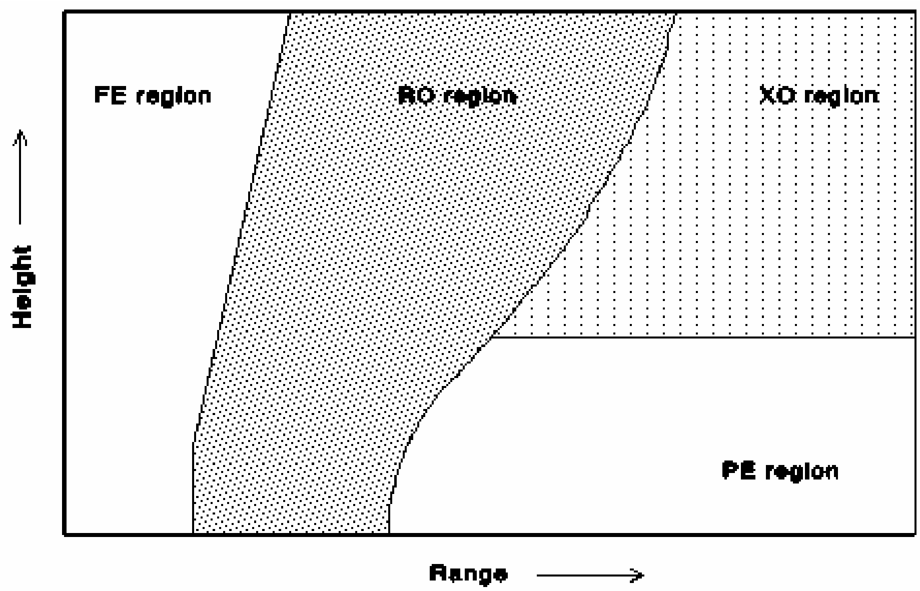

Figure 1. APM calculation regions.

For antenna elevation angles above 5 degrees or for ranges less than approximately 2.5 kilometers (km), a flat-earth (FE) ray-optics model is used. In this region, only receiver height is corrected for average refraction and earth curvature.

Within the RO region (as defined by a limiting ray), propagation loss is calculated from the mutual interference between the direct-path and surface-reflected ray components using the refractivity profile at zero range. Full account is given to focusing or de-focusing along direct and reflected ray paths and to the integrated optical path length difference between the two ray paths, to give precise phase difference, and, hence, accurate coherent sums for the computation of propagation loss.

For the low-altitude region beyond the RO region, a PE approximation to the Helmholtz full wave equation is employed. The PE model allows for range-dependent refractivity profiles and variable terrain along the propagation path and uses a split-step Fourier method for the solution of the PE. The PE model is run in the minimum region required to contain all terrain and trapping layer heights.

For the area beyond the RO region but above the PE region, an extended optics region (XO) is defined. Within the XO region, ray-optics methods that are initialized by the PE solution from below, are used.

APM will run in three “execution” modes depending on environmental inputs. APM will use the FE, RO, XO, and PE models if the terrain profile is flat for the first 2.5 km and if the antenna height is less than or equal to 100 m. It will use only the XO and PE models if the terrain profile is *not* flat for the first 2.5 km and if the antenna

height is less than or equal to 100 m. For applications in which the antenna height is greater than 100 meters, a combination of FE and PE methods are used. The FE model is used for all propagation angles greater than ±5º from the source and the PE model is used for angles within ±5º. By default, APM will automatically choose which mode of operation it will use for a specified set of inputs. However, the ability to run only the PE model for any case is allowed by setting a logical flag upon input. APM will automatically run only the PE algorithm for frequencies less than 50 MHz, regardless of the logical flag set by the user.

The APM CSCI allows for horizontal and vertical antenna polarization, finite conductivity based on user-specified ground composition and dielectric parameters, and the complete range of EM system parameters and most antenna patterns required by various external applications. APM also allows for gaseous absorption effects in all sub-models and computes troposcatter losses within the diffraction region and beyond.

The program flow of the required APM CSCI is illustrated Figure 2. Note that the APM CSCI is shown within the context of a calling CSCI application such as one that generates a coverage or loss diagram. The efficient implementation of the APM CSCI will have far reaching consequences on the design of an application CSCI beyond those mentioned in Section 3.10. For example, Figure 2 shows checking for the existence of a previously created APM output file prior to the access of the APM CSCI. The application CSCI will have to consider if the atmospheric or terrain environment has changed since the APM output file was created or if any new height or range requirement is accommodated within the existing APM CSCI output file. Because these and many more considerations are beyond the scope of this document to describe, an application CSCI designer should work closely with the APM CSCI development agency in the implementation of the APM CSCI. Figure 3 through Figure 6 illustrate the program flow for the main compute software components (CSC), APMINIT CSC, APMSTEP CSC, XOINIT CSC, and XOSTEP CSC, respectively.

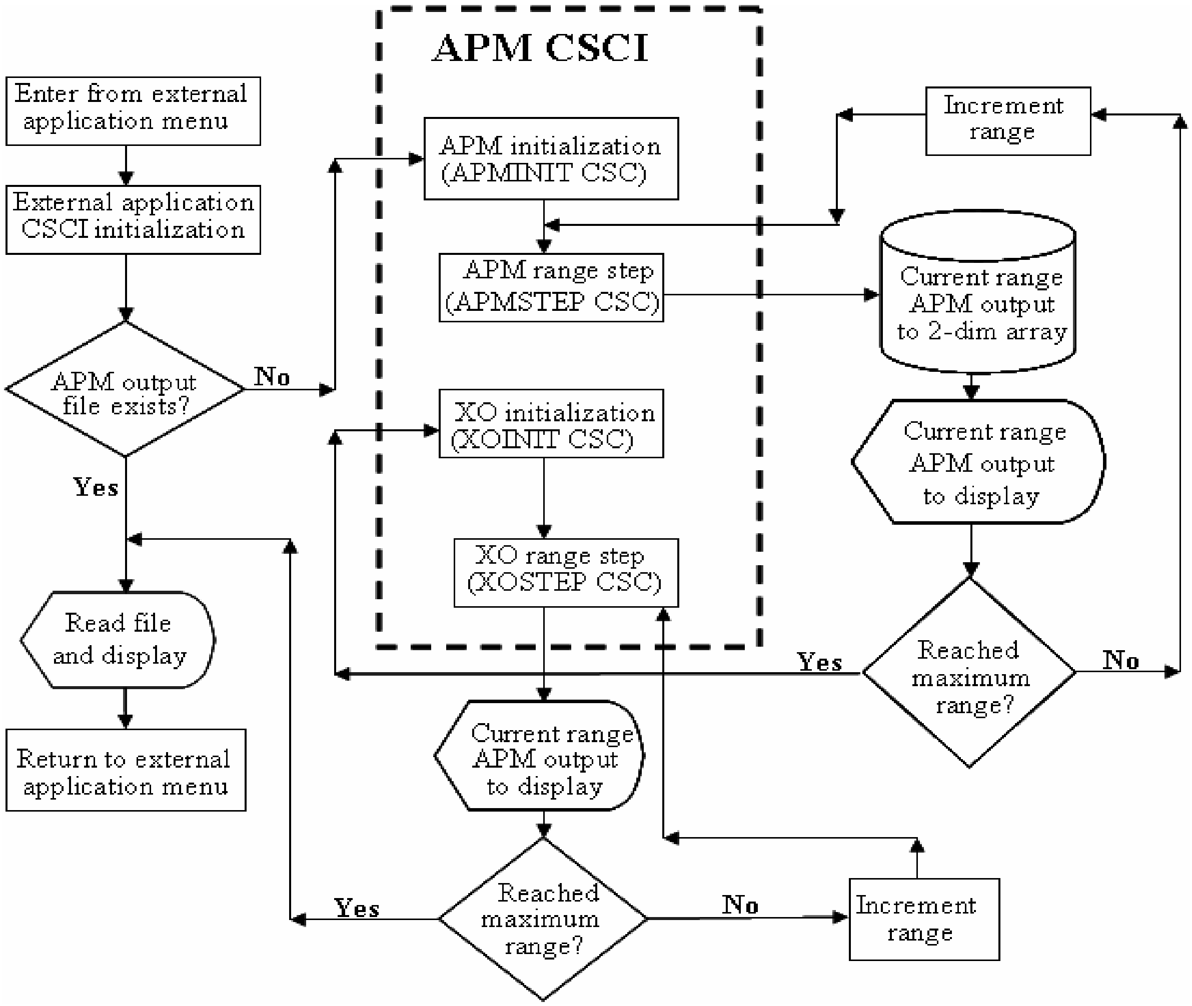

Figure 2. Program flow of the APM CSCI.

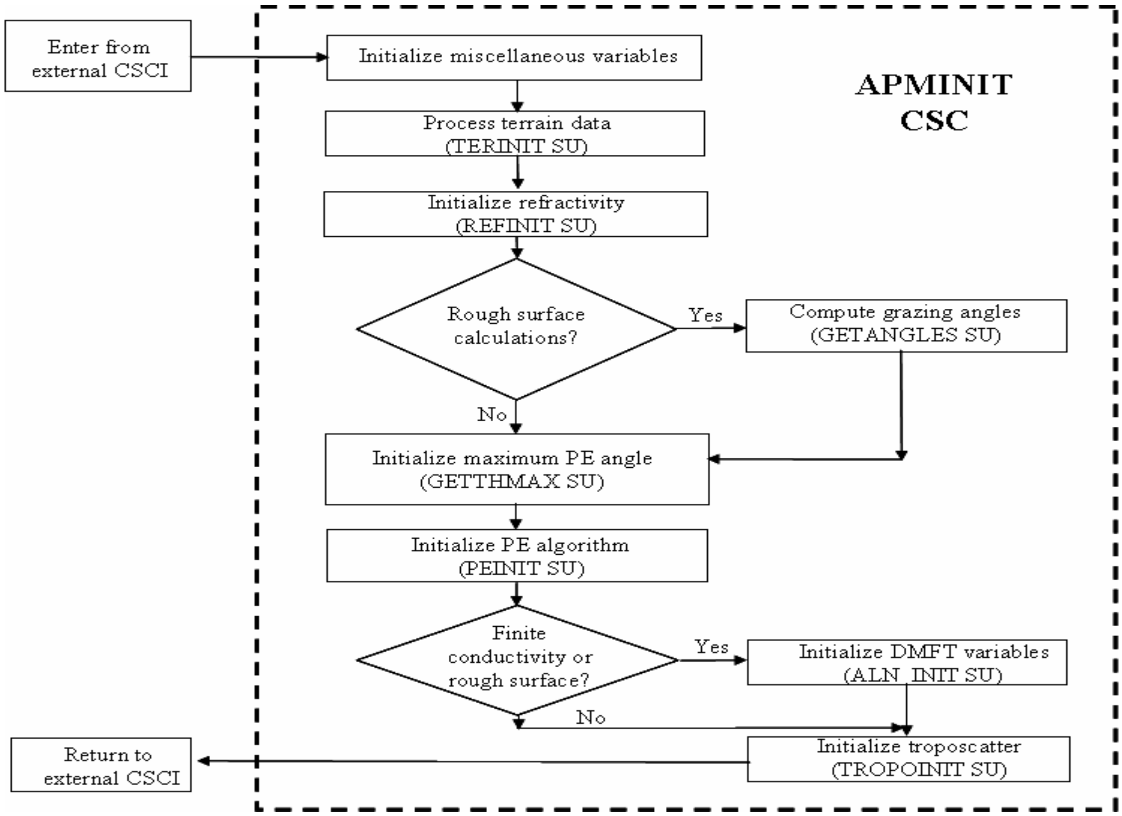

Figure 3. APMINIT CSC Program flow.

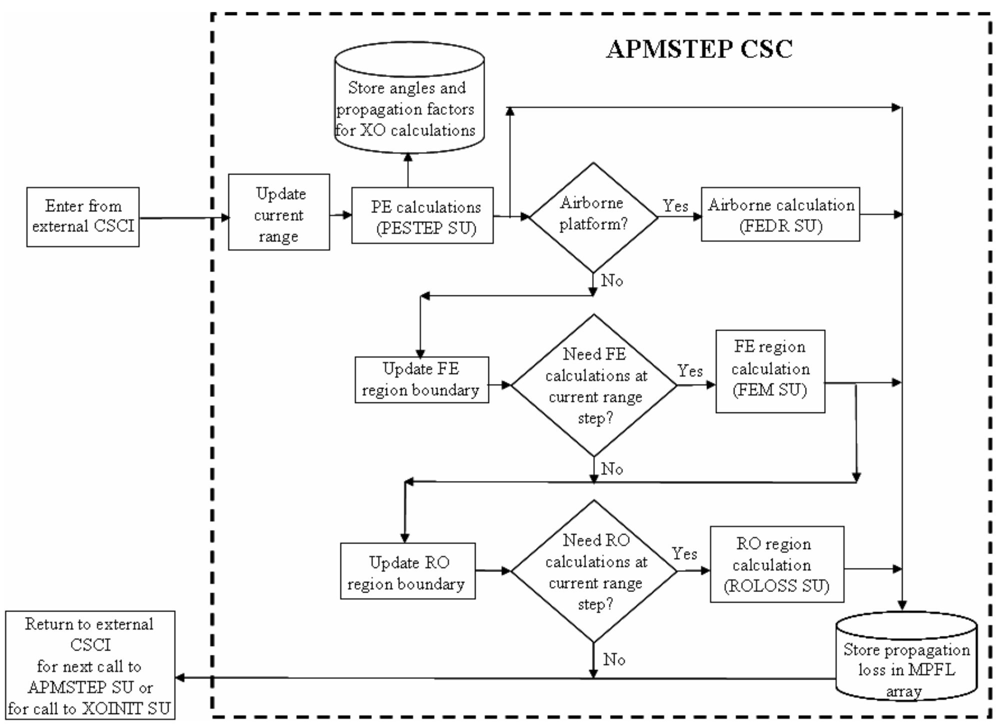

Figure 4. APMSTEP CSC Program flow.

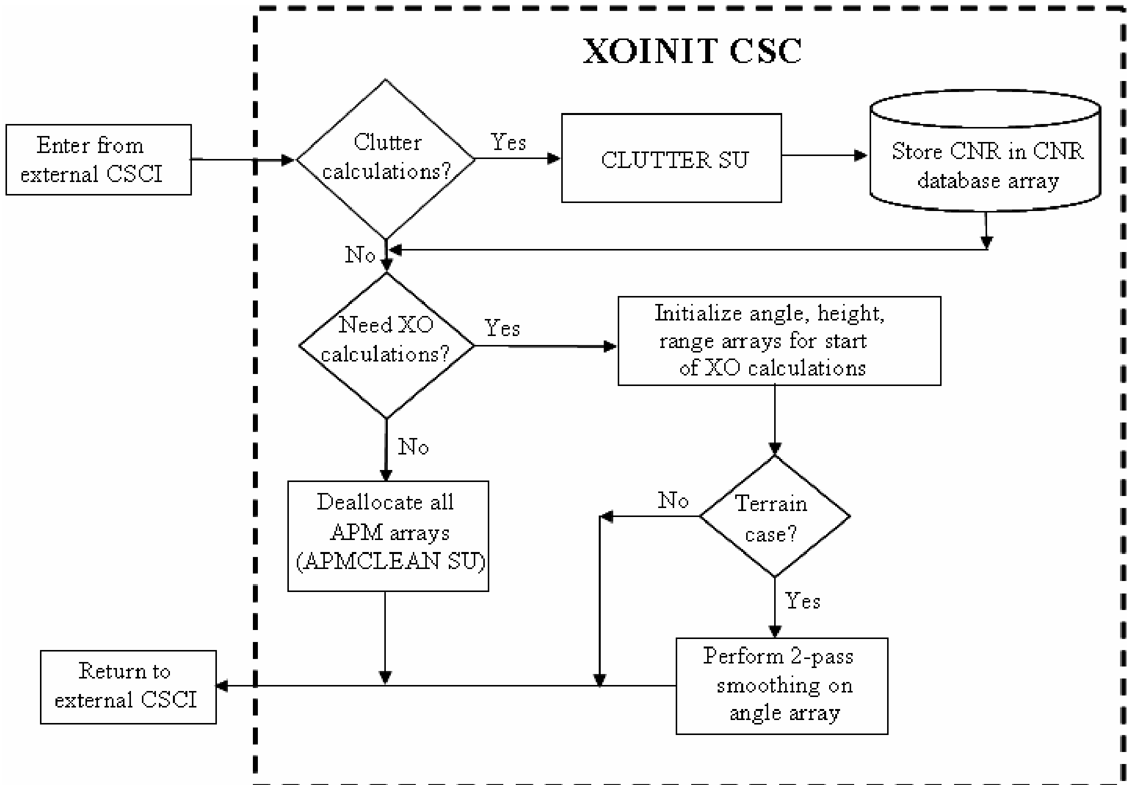

Figure 5. XOINIT CSC Program flow.

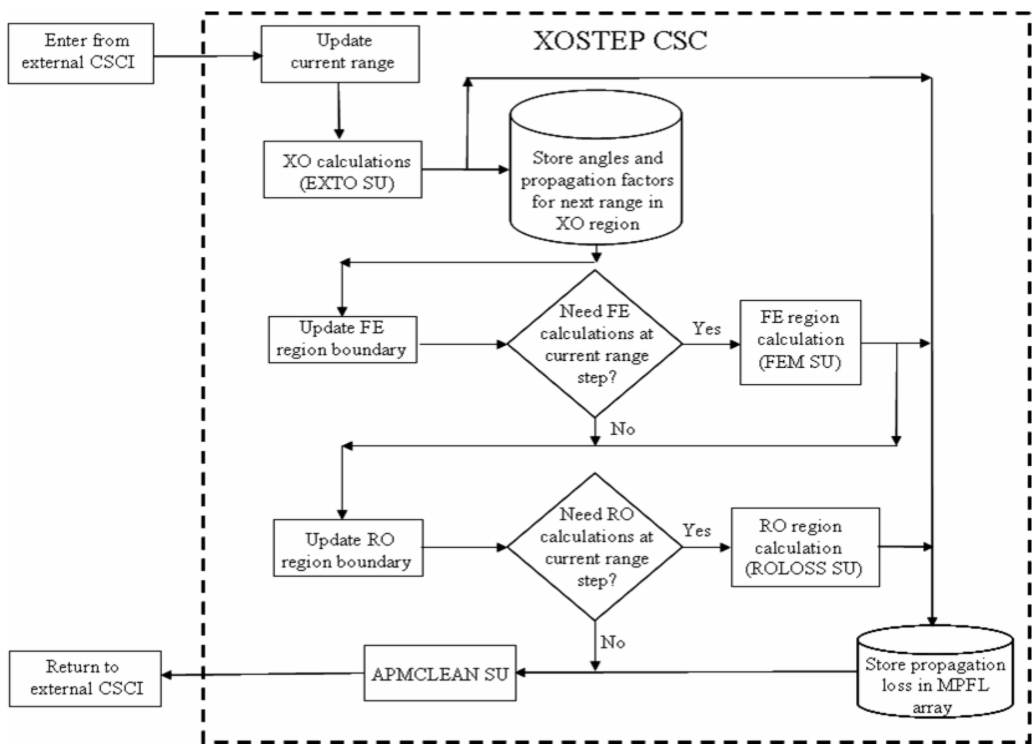

Figure 6. XOSTEP CSC Program flow.

The APM CSCI is divided into 5 main computer software components (CSC) and 67 additional software units (SU). The name, purpose, and a general description of processing required for each SU follows.

3.1.1 Advanced Propagation Model Initialization (APMINIT) CSC

The APMINIT CSC interfaces with various SUs for the complete initialization of the APM CSCI.

The atmospheric volume must be "covered" or resolved with a mesh of calculation points that will normally exceed the height/range resolution requirements of the particular application of the APM CSCI. Upon entering the APMINIT CSC, a range and height grid size per the APM CSCI output point is calculated from the number of APM outputs and the maximum CSCI range and height.

A TERINIT SU is referenced to examine the terrain profile. The minimum terrain height is determined, and then the entire terrain profile is adjusted by this height so that all internal calculations are referenced to this height. This is done in order to minimize the required PE transform size.

User-specified environmental and system parameters are examined to determine if the APM CSCI will execute in a full hybrid mode, a partial hybrid mode, or PE-only mode.

A REFINIT SU is referenced to initialize the external CSCI specified modified refractivity and also to test for valid environment profiles. A PROFREF SU adjusts the environment profiles by the internal reference height, and a INTPROF SU defines the modified refractivity at all PE vertical mesh points.

If rough surface calculations are required (i.e., a non-zero wind speed is specified) a GETANGLES SU is referenced to determine the grazing angles for the given refractivity profile. The grazing angles are then sorted and a GRAZE_INT SU is referenced to combine grazing angles computed by both methods (if necessary) and interpolate for subsequent use in rough surface calculations.

To automatically determine the maximum PE calculation angle, a GETTHMAX SU is referenced. This determines, via ray tracing, the minimum angle for which adequate coverage can be given with the specified terrain and environment profile. A FFTPAR SU is referenced to determine the fast Fourier transform (FFT) size for the calculated angle and to initialize data elements within the PE region which are dependent on the size of the FFT. The minimum size for the FFT is determined from the Nyquist criterion. An option also exists to activate *only* the PE algorithm within the APM CSCI, regardless of inputs. If this option is enabled, the PE maximum calculation angle is supplied by the calling CSCI.

If vertical polarization is specified, then additional calculations are performed in the starter solution using Kuttler and Dockery's mixed transform method. In this case a DIEINIT SU is used to initialize dielectric ground constants. For general ground types, the permittivity and conductivity are calculated as a function of frequency from curve fits to the permittivity and conductivity graphs shown in recommendations and reports of the International Radio Consulting Committee.

A PE initialization SU (PEINIT) is referenced to initialize all variables and arrays associated with PE calculations. A XYINIT SU and an antenna pattern factor SU (ANTPAT) are referenced to generate a first solution to the PE. A FFT SU is referenced for data elements required in obtaining the PE's starting solution.

If rough surface calculations are required, or if one is performing a finite-conducting boundary case, then a ALN_INIT SU is referenced to initialize field variables used in the mixed transform algorithm.

If running in a full hybrid mode, a FILLHT SU is referenced to determine the heights at each output range separating the FE, RO, and PE calculation regions. If running in a partial hybrid or PE-only mode, then the heights at each output range are determined, below which, propagation loss/factor solutions are valid. No propagation loss/factor solutions are provided above these heights for those execution modes.

A TROPOINIT SU is referenced to initialize all variables and arrays associated with troposcatter calculations and is referenced only if the user has enabled the T_{ropo} flag.

Finally, a GASABS SU is referenced to initialize the attenuation parameter due to oxygen and water vapor absorption.

3.1.1.1 Allocate Arrays APM (ALLARRAY_APM) SU

The ALLARRAY_APM SU allocates and initializes all dynamically dimensioned arrays associated with APM terrain, refractivity, troposcatter, and general variable arrays.

3.1.1.2 Allocate Array PE (ALLARRAY_PE) SU

The ALLARRAY_PE SU allocates and initializes all dynamically dimensioned arrays associated with PE calculations.

3.1.1.3 Allocate Array RO (ALLARRAY_RO) SU

The ALLARRAY_RO SU allocates and initializes all dynamically dimensioned arrays associated with RO calculations.

3.1.1.4 Allocate Array XORUF (ALLARRAY_XORUF) SU

The ALLARRAY_XORUF SU allocates and initializes all dynamically dimensioned arrays associated with XO and rough surface calculations.

3.1.1.5 Alpha Impedance Initialization (ALN_INIT) SU

The ALN_INIT SU initializes variables used in the discrete mixed Fourier transform (DMFT) algorithm for finite conductivity and/or rough surface calculations.

3.1.1.6 Antenna Pattern (ANTPAT) SU

The ANTPAT SU calculates a normalized antenna gain (antenna pattern factor) for a specified antenna elevation angle.

From the antenna beam width, elevation angle (an angle for which the antenna pattern factor is desired), and the antenna radiation pattern type; an antenna factor is calculated.

3.1.1.7 APM Status (APMSTATUS) SU

The APMSTATUS SU accesses the current status of APM calculations of the grazing angle. The SU is declared as an external subroutine within the main driver program.

3.1.1.8 Dielectric Initialization (DIEINIT) SU

The DIEINIT SU determines the conductivity and relative permittivity as functions of frequency in MHz based on general ground composition types.

3.1.1.9 FFT Parameters (FFTPAR) SU

The FFTPAR SU determines the required transform size based on the maximum PE propagation angle and the maximum height needed. If running in full or partial hybrid modes, the maximum height needed is the height necessary to encompass at least 20% above the maximum terrain peak along the path or the highest trapping layer specified in the environment profiles, whichever is greater. If running in a PE-only mode, the maximum height needed is the specified maximum output height. An error is returned if the computed transform size reaches 2^{30}.

For computational efficiency reasons, an artificial upper boundary must be established for the PE solution. To prevent upward propagating energy from being “reflected” downward from this boundary and contaminating the PE solution, the PE solution field strength should be attenuated or “filtered” above a certain height to ensure that the field strength just below this boundary is reduced to zero.

The total number of vertical points for which a transformation will be computed is determined. This term is also referred to as the FFT size. The filtering boundary height is also determined.

3.1.1.10 Fill Height Arrays (FILLHT) SU

The FILLHT SU calculates the effective earth radius for an initial launch angle of 5° and to fill an array with height values at each output range of the limiting sub-model, depending on which mode is being used. If running in a full hybrid mode, the array

contains height values at each output range separating the FE from the RO region. If running in other modes, the array contains those height values at each output range at which the initial launch angle has been traced to the ground or surface. For an execution mode in which PE and XO models are used, these height values represent the separating region where, above that height, valid loss is computed, and below that height, no loss is computed. This is done so only loss values that fall within a valid calculation region are output. For airborne applications in which a combination of PE and FE models are used, the array contains the height values at each range separating the FE and PE regions.

3.1.1.11 Gaseous Absorption (GASABS) SU

The GASABS SU computes the specific attenuation based on air temperature and absolute humidity. This SU is based on CCIR (International Telecommunication Union, International Radio Consultative Committee, now the ITU-R) Recommendation 676-1, "Attenuation by Atmospheric Gases in the Frequency Range 1-350 GHz."

3.1.1.12 Get Effective Earth Radius Factor (GET_K) SU

The GET_K SU computes the effective earth radius factor and the effective earth radius. The computation is made for a launch angle of 5º if the SU is called from the APMINIT CSC. If called from the TROPOINIT SU, then the computation is made for a launch angle equal to the critical angle.

3.1.1.13 Get Alpha Impedance (GETALN) SU

The GETALN SU computes the impedance term in the Leontovich boundary condition, and the complex index of refraction for finite conductivity, vertical polarization, and rough sea surface calculations. These formulas follow Kuttler and Dockery 's method.

3.1.1.14 Get Angles (GETANGLES) SU

The GETANGLES SU computes the grazing angles at each PE range step for subsequent use in rough sea surface calculations, and also computes the propagation angles within the PE region for subsequent output via the APMSTEP CSC if so desired. Two methods are used to compute the grazing angle. The first method uses ray trace by referencing a RGTRACE SU to compute grazing angles. The second is done by spectral estimation of the near-surface PE field. The near-surface PE field is computed by performing a "PE run" for a smooth-surface, perfect-conducting, horizontal polarization case at a fixed frequency (10 GHz) and fixed PE maximum calculation angle (4°).

3.1.1.15 Get Maximum Angle (GETTHMAX) SU

The GETTHMAX SU performs an iterative ray trace to determine the minimum angle required (based on the reflected ray) in obtaining a PE solution. The determination of this angle will depend on the particular mode of execution. For the full and partial hybrid modes, a ray is traced up to a height that exceeds at least 20% above the maximum terrain peak along the path or the highest trapping layer specified in the environment profiles, whichever is greater. The maximum PE propagation angle is then determined from the local maximum angle of the traced ray.

3.1.1.16 Grazing Angle Interpolation (GRAZE_INT) SU

The GRAZE_INT SU interpolates grazing angles at each PE range step based on angles computed from ray trace (takes precedence) and those computed from spectral estimation. These are used for subsequent rough surface calculations.

3.1.1.17 Height Check (HTCHECK) SU

The HTCHECK SU determines if the current traced height is below the current ground height. If so, it will calculate the reflection point and return with the modified angle, range, and height of reflection.

3.1.1.18 Interpolate Profile (INTPROF) SU

The INTPROF SU performs a linear interpolation vertically with height on the refractivity profile. Interpolation is performed at each PE mesh height point.

3.1.1.19 PE Initialization (PEINIT) SU

The PEINIT SU initializes all variables used in the PE model for subsequent calls to the PESTEP SU. The PE calculation height mesh and range step size are determined. The free-space propagator term is computed at each PE angle, or p-space, mesh point using the wide-angle propagator. A filter, or attenuation function (frequently called "window"), is applied to the upper one-quarter of the array corresponding to the highest one-quarter of the maximum propagation angle. Next, the environmental phase term is computed at each PE height, or z-space, mesh point (if performing a smooth surface, refractive homogeneous case). A filter, or attenuation function (frequently called "window"), is applied to the upper one-quarter of the mesh points corresponding to the highest one-quarter of the calculation height domain. Finally, a XYINIT SU is referenced to initialize the PE starting field.

3.1.1.20 Poly 4 (FN_POLY4) Function

The FN_POLY4 function evaluates a fourth degree polynomial.

3.1.1.21 Poly 5 (FN_POLY5) Function

The FN_POLY5 function evaluates a fifth degree polynomial.

3.1.1.22 Profile Reference (PROFREF) SU

The PROFREF SU adjusts the current refractivity profile so that it is relative to a reference height. The reference height is initially the minimum height of the terrain profile. Upon subsequent calls from the PESTEP SU, the refractivity profile is adjusted by the local ground height at each PE range step.

3.1.1.23 Refractivity Initialization (REFINIT) SU

The REFINIT SU checks for valid environmental profile inputs and initializes all refractivity arrays.

The environmental data are checked for a range-dependent profile and tested to determine if the range of the last profile entered is less than the maximum output range specified. If so, an integer error flag is returned and the SU exited, depending on the values of logical error flags set in the external calling CSCI itself.

The REFINIT SU also tests for valid refractivity level entries for each profile. If the last gradient in any profile is negative, it returns an integer error flag and the SU is exited. If no errors are detected, the REFINIT SU then extrapolates the environmental profiles vertically to 1000 km in height. Extrapolation is not performed horizontally from the last provided profile; rather, the last provided environment profile is duplicated at 10^7 km in range. This duplication of profiles is performed by the REFINTER SU. Finally, the REFINIT SU checks if an evaporation duct profile has been specified.

3.1.1.24 Remove Duplicate Refractivity Levels (REMDUP) SU

The REMDUP SU removes any duplicate refractivity levels in the currently interpolated profile.

3.1.1.25 RG Trace (RGTRACE) SU

The RGTRACE SU performs ray traces of many rays launched within an angle of ±4°. All angles from rays striking the surface are then sorted and stored for subsequent interpolation in the GRAZE_INT SU.

3.1.1.26 Terrain Initialization (TERINIT) SU

The TERINIT SU examines and initializes terrain arrays for subsequent use in PE calculations. It tests for and determines a range increment if it is found that range/height points are provided in fixed range increments. The minimum terrain height is determined and the entire terrain profile is adjusted so all internal calculations are referenced to this height. This is done in order to minimize the PE transform calculation volume.

3.1.1.27 Trace to Output Range (TRACE_ROUT) SU

The TRACE_ROUT SU traces a single ray, whose launch angle is specified by the calling routine, to each output range. The height of this ray is stored at each output range for subsequent proper indexing and accessing of the appropriate sub-models.

3.1.1.28 Trace to next Step (TRACE_STEP) SU

The TRACE_STEP SU performs one ray trace step for a given starting angle, range, and height. When passed a starting angle, range, and height for a single ray, it will trace to the first boundary that occurs, whether that is a refractivity level or the surface. It then passes back the ending angle, range and height and a flag indicating if the ray has hit the surface.

3.1.1.29 Troposcatter Initialization (TROPOINIT) SU

The TROPOINIT SU initializes all variables and arrays needed for subsequent troposcatter calculations. The tangent range and tangent angle are determined from the source and from all receiver heights and stored in arrays.

3.1.1.30 Starter Field Initialization (XYINIT) SU

The XYINIT SU calculates the complex PE solution at range zero.

Several constant terms that will be employed over the entire PE mesh are calculated. These terms are the angle difference between mesh points in p-space and a height-gain value at the source (transmitter).

For each point in the PE p-space mesh, the antenna pattern ANTPAT SU is referenced to obtain an antenna pattern factor for a direct-path ray and a surface-reflected ray. The complex portions of the PE solution are then determined from the antenna pattern factors, elevation angle, and antenna height. The initial field assumes the source is over a perfectly conducting ground.

3.1.2 Advanced Propagation Model Step (APMSTEP) CSC

The APMSTEP CSC advances the entire APM CSCI algorithm one output range step, referencing various SUs to calculate the propagation loss at the current output range. At this current range, APM calculations will be made within the vertical (up to the maximum PE height region) by accessing the appropriate region's SUs.

The current output range is determined. The PESTEP SU is referenced to obtain the PE portion of the propagation loss at this new range.

For an airborne application, the FEDR SU is referenced to obtain the FE portion of the propagation loss above and below the PE maximum propagation angle.

If running in full hybrid mode, then based upon a height array index used within the FE region, a determination is made for the necessity to include FE propagation calculations. If so, the FEM SU is referenced to obtain the FE portion of the propagation loss. If a FE calculation is made, the maximum height index for the RO region is adjusted (with the minimum height index corresponding to the maximum height index of the PE region), and the ROLOSS SU is referenced to obtain the RO portion of the propagation loss at the current range. FE and RO propagation loss will be computed only up to the range at which XO calculations will be performed.

If running in a partial hybrid (PE + XO) mode, then only the PESTEP SU will be referenced to obtain the PE portion of the propagation loss at this new range.

Finally, absorption loss is computed for the current range and added to the propagation loss at all heights.

3.1.2.1 Calculate Propagation Loss (CALCLOS) SU

The CALCLOS SU determines the propagation loss from the complex PE field at each output height point at the current output range.

The local ground height at the current output range is determined. All propagation loss/factor values at output height points up to the local ground height are then set to -32766. The first valid loss point is determined corresponding to the first output height point above the ground height. Next, the last valid loss point is determined based on the smaller of the maximum output height or the height traced along the maximum PE propagation angle to the current output range.

From the height of the first valid loss point to the height of the last valid loss point, the GETPFAC SU is referenced to obtain the propagation factor in dB (field strength relative to free space) at all corresponding output heights at the previous and current PE ranges. Then, for each valid output height, horizontal interpolation in range is performed to obtain the propagation factor at the current output range. From the propagation factor and the free-space loss, the propagation loss at each valid output height is determined, with the propagation loss/factor set to -32767 for all output height points above the last valid output height but less than the maximum output height.

If running in full or partial hybrid modes, the propagation factor at the top of the PE region is determined at every output range and stored in an array for future reference in XO calculations. If troposcatter calculations are desired, the TROPOSCAT SU is referenced with the results added to the propagation loss/factor array. Absorption loss is computed for the current range and added to the propagation loss at all heights. All loss/factor values returned to the external CSCI at this point are in centibels (10 cB = 1 dB).

3.1.2.2 Current Wind (FN_CURWIND) Function

The FN_CURWIND function performs a linear interpolation in range to get the current wind speed at the specified range.

3.1.2.3 Dielectric Constant (FN_DIECON) Function

The FN_DIECON function extracts the complex dielectric constant at a particular range.

3.1.2.4 DoShift SU

The DOSHIFT SU shifts the complex PE field by the number of bins, or PE mesh heights corresponding to the local ground height.

Upon entering the number of bins to be shifted are determined. The PE solution is then shifted downward if the local ground is currently at a positive slope, and upward if the local ground is at a negative slope.

3.1.2.5 Discrete Sine/Cosine Fast-Fourier Transform (DRST) SU

A function with a common period, such as a solution to the wave equation, may be represented by a series consisting of sines and cosines. This representation is known as a Fourier series. An analytical transformation of this function, known as a Fourier transform, may be used to obtain a solution for the function.

The solution to the PE approximation to Maxwell's wave equation is to be obtained by using such a Fourier transformation function. The APM CSCI requires the real-valued sine and cosine transformations in which the real and imaginary parts of the PE equation are transformed separately. A Fourier transformation for possible use with the APM CSCI is described by Bergland (1969) and Cooley, Lewis, and Welsh (1970).

3.1.2.6 Flat-Earth Direct Ray (FEDR) SU

The FEDR SU determines propagation loss based on FE calculations for the direct ray path only for regions above and below the PE maximum propagation angle.

3.1.2.7 Flat-Earth Model (FEM) SU

The FEM SU computes propagation loss at a specified range based upon FE approximations. Receiver heights are corrected for earth curvature and average refraction based on twice the effective earth radius computed in the GET_K SU. The following steps are performed for each APM output height.

1. The path lengths and elevation angles for the direct-path and surface-reflected path, along with the grazing angle, are computed from simple right-triangle calculations. Using the two elevation angles, the ANTPAT SU is referenced to obtain an antenna pattern factor for each angle. Using the grazing angle, the GETREFCOEF SU is referenced to obtain the magnitude and phase lag of the surface reflection coefficient.

2. From the path length difference, the phase lag of the surface reflected ray, and the wave number, a total phase lag is determined. Using the total phase lag, the magnitude of the surface reflection coefficient and the two antenna pattern factors, the two ray components are coherently summed to obtain a propagation factor. The propagation factor, together with the free-space propagation loss and path length difference of the direct-path ray, are used to compute the propagation loss.

3.1.2.8 Fast-Fourier Transform (FFT) SU

The FFT SU separates the real and imaginary components of the complex PE field into two real arrays and then reference the DRST SU that transforms each portion of the PE solution.

3.1.2.9 Free Space Range Step (FRSTP) SU

The FRSTP SU propagates the complex PE solution field in free space by one range step.

The PE field is transformed to p-space and then multiplied by the free-space propagator. Before exiting, the PE field is transformed back to z-space. Both transforms are performed using a FFT SU.

3.1.2.10 FZLIM SU

The FZLIM SU determines the propagation factor (in dB) and the outgoing propagation angle at the top of the PE calculation region. These values, along with the corresponding PE range, are stored for future reference by the XOINIT SU.

The GETPFAC SU is referenced to determine the propagation factor at the last height mesh point in the valid part of the PE region. The propagation factor, along with the range and the local ray angle (determined from the ray traced separating the RO and PE regions), is stored if this is the first call to the FZLIM SU. The SPECEST SU is then referenced to determine the outgoing propagation angle. Depending on the change of angles from one range step to the next, the calculated outgoing angle will be limited. The storage array counter is incremented and the outgoing angle stored.

Before exiting, the SAVEPRO SU is referenced to store the refractivity profiles from the top of the PE region to the maximum specified coverage height.

3.1.2.11 Get Propagation Factor (FN_GETPFAC) Function

The FN_GETPFAC function determines the propagation factor at the specified height in decibels.

A vertical interpolation with height on the PE solution field is performed to obtain the magnitude of the field at the desired output height point. An additional calculation is made and the propagation factor is then returned in decibels.

3.1.2.12 Get Reflection Coefficient (GETREFCOEF) SU

The GETREFCOEF SU calculates the complex surface reflection coefficient, along with the magnitude and phase angle.

The complex reflection coefficient is computed from a specified grazing angle and is based on the Fresnel reflection coefficient equations for vertical and horizontal polarization. The magnitude and phase angle are determined from the complex reflection coefficient. If rough surface calculations are required, the smooth surface reflection coefficient is then modified by the Miller–Brown rough surface reduction factor, which is a function of wind speed and grazing angle.

3.1.2.13 Get Troposcatter Loss (FN_GET_TLOSS) Function

The FN_GET_TLOSS function determines the loss due to troposcatter and computes the appropriate loss from troposcatter and diffraction for a specific transmitter and receiver point over land and water. For each transmitter/receiver pair, the following steps are performed.

1. If the current output range is less than the minimum diffraction field range for a particular receiver height, then the SU is exited and no troposcatter loss is computed.

2. The tangent angle from the receiver height is determined.

3. The common volume scattering angle is determined and calculations are performed to obtain the loss due to troposcatter.

Troposcatter loss is compared to propagation loss. If the difference between the propagation loss and troposcatter loss is less than 18 dB, then the corresponding power levels of the two loss values are added. If the difference is greater than 18 dB, then the lesser of the two losses is used.

3.1.2.14 Linear Interpolation (FN_PLINT) Function

The FN_PLINT function performs a linear interpolation on two input parameters passed to the function.

3.1.2.15 Mixed Fourier Transform (MIXEDFT) SU

The MIXEDFT SU propagates the PE field in free space one PE range step, applying the Leontovich boundary condition, using the mixed Fourier transform as outlined by Kuttler and Dockery (1991). For finite conducting boundaries (i.e., if vertical polarization is specified or rough surface calculations are required) and the frequency is less than 400 MHz, the central difference form of the DMFT is used. If the frequency is greater than 400 MHz, the backward difference form of the DMFT is used.

3.1.2.16 Parabolic Equation Step (PESTEP) SU

The PESTEP SU advances the PE solution one output range step, referencing various SUs to calculate the propagation loss at the current output range.

The next output range is determined and an iterative loop begun to advance the PE solution such that for the current PE range, a PE solution is calculated from the solution at the previous PE range. This procedure is repeated until the output range is reached.

At each PE range step, the local ground height is determined and the PE field is "shifted" by the number of bins or PE mesh height points corresponding to the local ground height. This is performed in the DOSHIFT SU.

If the APM CSCI is used in a range-dependent mode, that is, more than one profile has been input; or a terrain profile is specified, the REFINTER SU is referenced to compute a new modified refractive index profile adjusted by the local ground height at the current range. A new environmental phase term is computed using this new refractivity profile.

If using vertical polarization and the current ground type has changed from the previous one, or rough surface calculations are required, a GETALN SU is referenced to determine the impedance term and all associated variables used for the mixed transform calculations.

If rough surface calculations are required, or if using vertical polarization, then a MIXEDFT SU is referenced, otherwise, a FRSTP SU is referenced to advance the PE solution one range step in free space. The environmental phase term is then applied to obtain the new final PE solution at the current range. Once all calculations are made to determine the PE field at the current PE range, the FZLIM SU is referenced to determine and store the outgoing propagation factor and propagation angle at the top of the PE region. The FZLIM SU is only referenced if running in full or partial hybrid modes. Finally, a CALCLOS SU is referenced to obtain the propagation loss/factor at the desired output heights at the current output range.

3.1.2.17 Ray Trace (RAYTRACE) SU

Using standard ray trace techniques, a ray is traced from a starting height and range with a specified starting elevation angle to a termination range. As the ray is being traced, an optical path length difference and a derivative of range with respect to elevation angle are being continuously computed. If the ray should reflect from the surface, a grazing angle is determined. Upon reaching the termination range, a terminal elevation angle is determined along with a termination height.

3.1.2.18 Refractivity Interpolation (REFINTER) SU

The REFINTER SU interpolates horizontally and vertically on the modified refractivity profiles. Profiles are then adjusted so they are relative to the local ground height.

If range-dependent refractive profiles have been specified, horizontal interpolation to the current PE range is performed between the two neighboring profiles. A REMDUP SU is referenced to remove duplicate refractivity levels, and the PROFREF SU is then referenced to adjust the new profile relative to the internal reference height corresponding to the minimum height of the terrain profile. The PROFREF SU is referenced once more to adjust the profile relative to the local ground height, and upon exit from the PROFREF SU, the INTPROF SU is referenced to interpolate vertically on the refractivity profile at each PE mesh height point.

3.1.2.19 Ray Optics Calculation (ROCALC SU)

The ROCALC SU computes the RO components needed in the calculation of propagation loss at a specified range and height within the RO region. These components are the amplitudes for a direct-path and surface-reflected ray, and the total phase lag angle between the direct-path and surface-reflected rays.

A test is made to determine if this is the first RO calculation. If an initial calculation is needed, the height, range, and elevation angle array indices are set to initial conditions. If not, the array indices are incremented from the previous RO calculation.

The following steps are performed for each series of vertical grid points, in a manner that ensures that RO calculations have been performed at ranges that span the current range of interest. The vertical grid points are taken in order, beginning with the one with the greatest height.

1. Using a Newton iteration method with a varying elevation angle, the RAYTRACE SU is referenced to find a direct-path ray and a surface-reflected ray originating at the transmitter height and terminating at the same grid point. Should a direct or reflected ray not be found to satisfy the condition, or should the computed grazing angle exceed the grazing angle limit, the height array index is adjusted to redefine the lower boundary of the RO region. Should the ray trace conditions be satisfied, the RAYTRACE SU will provide a terminal elevation angle, a derivative of range with respect to elevation angle, a path length, and for the surface-reflected ray, a grazing angle.

2. Using the final direct-path ray and surface-reflected ray elevation angles obtained from the Newton iteration method, the ANTPAT SU is referenced to obtain an antenna pattern factor for each angle. The GETREFCOEF SU is referenced to obtain the amplitude and phase lag angle of the surface reflection coefficient.

3. Using the antenna pattern factors, path length differences, and surface-reflection coefficients, the necessary RO components defined in the first paragraph above are calculated.

3.1.2.20 Ray Optics Loss (ROLOSS) SU

The ROLOSS SU calculates propagation factor and loss values at all valid RO heights at a specified range based based upon the components of magnitude for a direct-path and surface-reflected ray and the total phase lag angle between the two rays as determined by the ROCALC SU.

For purposes of computational efficiency, an interpolation from the magnitude and total phase lag arrays, established by the ROCALC SU, is made to obtain these three quantities at each APM vertical output mesh point within the RO region.

From the interpolated phase lag and ray amplitudes, a propagation factor is calculated that is used, in turn, with the free-space loss to obtain a propagation loss at each vertical APM output point. Absorption loss is computed for the current range and added to the propagation loss at all heights.

3.1.2.21 Save Profile (SAVEPRO) SU

The SAVEPRO SU stores refractivity profiles at each PE range step from the top of the PE region to the maximum user-specified height. This is only done if running in full or partial hybrid modes.

The refractivity height level just exceeding the PE region height limit is determined. From this level upward, all heights, M-units, and gradients are stored.

3.1.2.22 Spectral Estimation (SPECEST) SU

The SPECEST SU determines the outward propagation angle at the top of the PE calculation region or the grazing angle at the lower part of the PE region based on spectral estimation. The outward propagation angle is used for XO calculations and the grazing angle is used for rough surface calculations.

The upper 8 (if running smooth surface case) or 16 (if running terrain case) bins of the complex PE field at the current PE range are separated into their real and imaginary components. The upper ¼ of this portion of the field is then filtered and zero-padded to 256 points. It is then transformed to its spectral components via a reference to the DRST SU. The amplitudes of the spectral field are then determined and a 3-point average is performed. The peak of the 256-point field is found and the outgoing propagation angle is determined from the peak value.

3.1.2.23 Surface Impedance (SURFIMP) SU

The SURFIMP SU computes the normalized average surface impedance for surface wave propagation by vertically polarized waves along the sea surface. This is done for frequencies less than 50 MHz.

3.1.2.24 Troposcatter (TROPOSCAT) SU

The TROPOSCAT SU determines the loss due to troposcatter and to compute the appropriate loss from troposcatter and propagation loss for large receiver ranges.

The current output range is updated and the tangent angle from the source to the current output range is initialized. For all output receiver heights at the current output range, the following procedure is performed.

3.1.3 Extended Optics Initialization (XOINIT) CSC

The XOINIT SU initializes the range, height, and angle arrays in preparation for the XOSTEP CSC.

Upon entering, if XO calculations are not required, the APMCLEAN SU is referenced to deallocate all arrays used for the current application, then the CSC is exited.

If XO calculations are required, all arrays used for XO calculations are allocated and initialized to 0. The ranges and angles previously stored from referencing the FZLIM SU are now used to initialize the range and angle arrays for XO calculations. A 10-point smoothing average on the angle array is performed twice via reference to the MEANFILT SU. Upon exiting, the height array and initial height index for start of XO calculations are initialized.

3.1.3.1 Advanced Propagation Model Clean (APMCLEAN) SU

The APMCLEAN CSC deallocates all dynamically dimensioned arrays used in one complete run of APM calculations.

3.1.3.2 Clutter-to-Noise (CLUTTER) SU

The CLUTTER SU computes the clutter-to-noise ratio in dB at each output range based on the radar range equation over land or water.

The clutter is computed over water based on a modification to the Georgia Institute of Technology (GIT) reflectivity model, which is valid for frequencies greater than 1 GHz.

For those portions of the path over land the reflectivity is determined based on the "constant-gamma" model, where a parameter describing the backscattering effectiveness of the surface must be provided.

3.1.3.3 Diffraction Loss (FN_DLOSS) Function

The FN_DLOSS function computes loss in the diffraction region based on the CCIR model for standard atmosphere.

3.1.3.4 Get Theta (GETTHETA) SU

The GETTHETA SU calculates the optical phase-lag difference angle from the reflection range found in the R1ITER SU.

3.1.3.5 GIT Initialization (GIT_INIT) SU

The GIT_INIT SU initializes all variables used in the calculation of the reflectivity based on a modified version of the GIT model.

3.1.3.6 GofZ (GOFZ) Function

The GOFZ function calculates the diffraction region height-gain in dB from the CCIR diffraction region model for standard atmosphere.

3.1.3.7 Mean Filter (MEANFILT) SU

The MEANFILT SU performs an n-point average smoothing on any array passed to it.

3.1.3.8 Optical Region Limit (OPLIMIT) SU

The OPLIMIT SU calculates the maximum range in the optical interference region and the corresponding loss at that range.

3.1.3.9 Optical Difference (OPTICF) SU

The OPTICF SU calculates the optical path-length difference angle by solving a cubic equation for the reflection point range.

3.1.3.10 R1 Iteration (R1ITER) SU

The R1ITER SU finds the range of the reflection point corresponding to a particular launch angle.

3.1.3.11 Standard Propagation Model Initialization (SPM_INIT) SU

The SPM_INIT SU initializes many of the variables used throughout the SPM SU.

3.1.3.12 Standard Propagation Model (SPM) SU

The SPM SU computes the propagation factor for a standard atmosphere only, with the assumption of omni-directional antenna patterns.

3.1.4 Extended Optics Step (XOSTEP) CSC

The XOSTEP CSC advances the APM CSCI algorithm one output range step from the top of the PE calculation region to the maximum output height specified, referencing various SUs to calculate the propagation loss and factor at the current output range.

Upon entering the XOSTEP CSC, the current output range is determined. The EXTO SU is referenced to obtain the XO portion of the propagation loss and factor at this new range.

If running in full hybrid mode, based on a height array index used within the FE region, determine if it is necessary to include FE propagation calculations. If necessary, the FEM SU is referenced to obtain the FE portion of the propagation loss and factor. If an FE calculation is made, the maximum height index for the RO region is adjusted (with the minimum height index corresponding to the maximum height index of the PE region), and the ROLOSS SU is referenced to obtain the RO portion of the propagation loss and factor at the current range.

If running in partial hybrid mode, then only the EXTO SU is referenced to obtain the XO portion of the propagation loss and factor at this new range. The maximum height will correspond to the maximum user-specified coverage height.

Finally, the APMCLEAN SU is referenced to deallocate all allocated arrays used throughout the run.

3.1.4.1 Extended Optics (EXTO) SU

The EXTO SU calculates propagation loss and factor, based on extended optics techniques, at the current output range.

Upon entering, array indices for the current range, height, and angle arrays are initialized. A ray trace is then performed for all rays from the last output range to the current output range. The current heights are then sorted, along with their corresponding propagation factors. The propagation loss is then determined at each output receiver height by interpolation on the terminal heights of the traced rays.

Upon exiting, a reference to the TROPOSCAT SU provides any troposcatter losses and is added to the loss array. Absorption loss is also added to the propagation loss at all heights.

3.1.5 Return Grazing Angle (RET_GRAZE) CSC

The RET_GRAZE CSC interpolates the grazing angle to every output range step, and if necessary, will interpolate the propagation angles in height at every output range.

3.2 CSCI EXTERNAL INTERFACE REQUIREMENTS

The APM CSCI is accessed through the APMINIT CSC by a subroutine call from the external CSCI, which should provide, as global data elements, the values specified in Table 1 through Table 4.

The APM CSCI external data elements, i.e., those data that must be provided by the calling external CSCI prior to the APM CSCI execution may be divided into four classifications. The first classification is external data related to the atmospheric environment (Table 1), the second is data related to the EM system (Table 2), the third is data related to the implementation of the APM CSCI by the external CSCI (Table 3), and the fourth is data related to the terrain information (Table 4). Each table lists the type, units, and bounds of each data element. Table 5 specifies the output data of the APM CSCI model.

Table 1. APM CSCI environmental data element requirements.

Name	Description	Type	Units	Bounds
refmsl	Modified refractivity profile (dynamically allocated) array referenced to mean sea level	real	M	≥ 0.0[a]
hmsl	Profile height (dynamically allocated) array	real	meters	See note b
n_{prof}	Number of refractivity profiles	integer	N/A	≥ 1
lvlp	Number of profile levels	integer	N/A	≥ 2
rngprof	Dynamically allocated array of ranges to each profile	real	meters	≥ 0.0
abs_{hum}	Surface absolute humidity	real	g/m^3	0 to 50[c]
t_{air}	Surface air temperature	real	°C	-20 to 40[c]
γ_a	Surface specific attenuation	real	dB/km	≥ 0.0
i_{extra}	Extrapolation flag for refractivity profiles entered in combination with terrain below mean sea level	integer	N/A	0 or 1
n_w	Number of wind speeds and corresponding ranges	integer	N/A	≥ 0.0
rngwind	Dynamically allocated array of ranges specified for each wind speed in *wind()*.	real	meters	≥ 0.0
wind	Dynamically allocated array of wind speeds.	real	meters/ second	0.0 to 20.0[d]
$wind_{dir}$	Angle between antenna boresight and upwind direction	real	degrees	0.0 to 360.0

[a]Couplets of height and modified refractivity associated with that height are referred to within this document as a refractivity profile.

[b]All heights in the refractivity profile must be steadily increasing.

[c]The CCIR gaseous absorption model implemented within APM provides a ±15% accuracy for absolute humidity and surface air temperature within these bounds. While values beyond these limits are allowed within APM, note that this may result in less accurate attenuation rates being calculated.

[d]The maximum wind speed will vary depending on frequency. For frequencies less than 10 GHz, the maximum that can be specified is 20 m/s. Above 10 GHz, the maximum wind speed that can be specified will decrease to an absolute maximum of 15 m/s at 20 GHz and above.

Table 2. APM CSCI external EM system data element requirements.

Name	Description	Type	Units	Bounds
μ_{bw}	Antenna vertical beam width	real	degree	0.5 to 45
μ_o	Antenna elevation angle	real	degree	-10.0 to 10.0
C_{lut}	Logical flag used to indicate if surface clutter calculations are desired.	logical	N/A	'.true.' or '.false.'
f_{MHz}	EM system frequency	real	MHz	2.0 to 20,000.0[a]
i_{pat}	Antenna pattern 1 = Omnidirectional 2 = Gaussian 3 = Sine (X)/X 4 = Cosecant-squared 5 = Generic height-finder 6 = User-defined height-finder 7 = User-defined antenna pattern 8 = Quarter-wave dipole	integer	N/A	1 to 8
i_{pol}	Antenna polarization 0 = Horizontal 1 = Vertical	integer	N/A	0 to 1
G	Gain of transmit/receive antennas	real	dBi	$\geq$ 0.0
ant_{ht}	Antenna height above local ground at range 0.0 m	real	meters	$\geq$ 1.5[b]
$hfang$	Dynamically allocated user-defined height-finder power reduction angle array (i_{pat}=6) or antenna pattern angles (i_{pat}=7)	real	degree	0.0 to 90.0 for i_{pat}=6 -90.0 to 90.0 for i_{pat}=7
$hffac$	Dynamically allocated user-defined power reduction factor array (i_{pat}=6) or antenna pattern factors (i_{pat}=7)	real	N/A	0.0 to 1.0
L_{sys}	Miscellaneous system losses	real	dB	$\geq$ 0.0
θ_{hbw}	Antenna horizontal beam width	real	degrees	0.5 to 45
n_{facs}	Number of power reduction angles/factors for user-defined height finder antenna pattern	integer	N/A	1 to 10
N_f	Noise figure	real	dB	$\geq$ 0.0
P_t	Transmitter peak power	real	kW	$\geq$ 0.1
τ	Pulse length/width	real	μsec	$\geq$ 0.1

[a]The frequency can be specified greater than 20 GHz; however, the PE_{flag} must be set to '.true.' and care must be taken in specifying th_{max} and r_{mult}.

[b]The minimum antenna height will vary depending on the frequency and beamwidth according to the formula:

$$ant_{ht} \geq maximum\ of \left(1.5, 0.6\frac{c_o}{f_{MHz}\ \mu_{bw}}\right)$$

where c_o is the speed of light x 10^{-6} m/s (299.79245).

Table 3. APM CSCI external implementation data element requirements.

Name	Description	Type	Units	Bounds
h_{max}	Maximum height output for a particular application of APM	real	meters	≥ 100.0[a]
h_{min}	Minimum height output for a particular application of APM	real	meters	≥ 0.0[a]
lang	Propagation angle and factor output flag '.true.'= Output propagation angle and propagation factor for direct and reflected ray (where applicable). '.false.' = Do not output propagation angles and factors	logical	N/A	'.true.' or '.false.'[b]
lerr6	Logical flag to allow for error -6 to be bypassed	logical	N/A	'.true.' or '.false.'[c]
lerr12	Logical flag to allow for error -12 to be bypassed	logical	N/A	'.true.' or '.false.'[c]
n_{rout}	Number of range output points for a particular application of APM	intege r	N/A	≥ 1
n_{zout}	Number of height output points for a particular application of APM	intege r	N/A	≥ 1
n_{zout_rtg}	Number of height output points for receiver heights relative to the local ground elevation.	intege r	N/A	≥ 0
PE_{flag}	Flag to indicate use of PE algorithm only: '.true.' = only use PE sub-model '.false.' = use automatic hybrid model	logical	N/A	'.true.' or '.false.'[c]
r_{max}	Maximum range output for a particular application of APM	real	meters	≥ 5000.0[c]
r_{mult}	PE-range step multiplier	real	N/A	> 0.0[c]
th_{max}	Visible portion of PE maximum calculation angle	real	degree s	> 0.0[c]
T_{ropo}	Logical flag to include troposcatter calculations.	intege r	N/A	'.true.' or '.false.'
zout_rtg	Dynamically allocated array of receiver heights specified relative to the local ground height.	real	meters	≥ 0.0

[a]Refer to section 7.2 for a complete description.

[b]This flag should <u>not</u> be enabled when any portion of the propagation path is over land.

[c]Refer to section 4.3.4 for a complete description.

Table 4. APM CSCI external terrain data element requirements.

Name	Description	Type	Units	Bounds
terx	Dynamically allocated terrain profile range array	real	meters	≥ 0.0[a]
tery	Dynamically allocated terrain profile height array	real	meters	≥ 0.0[a]
γc	Dynamically allocated array of constants describing the backscattering effectiveness of the surface	real	dB	$-100.0 \le \gamma c \le 100.0$
γrng	Dynamically allocated array of ranges corresponding to the values in γc	real	meters	≥ 0.0
i_{gc}	Number of γc values for a particular application of APM	integer	N/A	≥ 0
i_{tp}	Number of terrain profile points for a particular application of APM	integer	N/A	≥ 2
i_{gr}	Number of ground types for a particular application of APM	integer	N/A	≥ 0[a]
igrnd	Array of ground composition types for a particular application of APM 0 = Sea water 1 = Fresh water 2 = Wet ground 3 = Medium dry ground 4 = Very dry ground 5 = Ice at -1° C 6 = Ice at -10° C 7 = User-defined	integer	N/0A	$0 \le igrnd \le 7$[a]
rgrnd	Dynamically allocated array of ranges for which ground types are applied for a particular application of APM	real	meters	≥ 0.0[a]
dielec	Dynamically allocated two-dimensional array of relative permittivity (ε_r) and conductivity (σ) for a particular application of APM	real	ε_r - N/A σ- Siemens/ meter	>0[a]

[a]refer to section 7.3 for a complete description

Table 5. APM CSCI output data element requirements.

Name	Description	Type	Units	Source
CNR	Clutter-to-Noise ratio array	real	dB	XOINIT CSC
Ψ_{rout}	Array of grazing angles at each output range r_{out}	real	radians	RET_GRAZE SU
i_{error}	Integer value that is returned if an error occurs in called routine	integer	N/A	APMINIT CSC RET_GRAZE SU XOINIT CSC
i_{xostp}	Index of output range step at which XO model is to be applied	integer	N/A	APMINIT CSC
j_{end}	Output height index at which valid propagation loss values end	integer	N/A	APMSTEP CSC
j_{start}	Output height index at which valid propagation loss values begin	integer	N/A	APMSTEP CSC
j_{xend}	Output height index at which valid XO propagation loss values end	integer	N/A	XOSTEP CSC
j_{xstart}	Output height index at which valid XO propagation loss values begin	integer	N/A	XOINIT CSC
l_{graze}	Logical flag indicating if grazing angles were computed for a particular application of APM	logical	N/A	APMINIT CSC
$mpfl$	Propagation loss and factor array	integer	cB	APMSTEP CSC XOSTEP CSC
$mpfl\_rtg$	Propagation loss and factor at receiver heights specified in the $zout\_rtg$ array	integer	cB	APMSTEP CSC
$propaf$	Two-dimensional array, containing the propagation angles and factors for the direct and reflected rays (where applicable) for all output height/range points	real	radians,dB	APMSTEP CSC XOSTEP CSC
r_{out}	Current output range	real	meters	APMSTEP CSC XOSTEP CSC

3.3 CSCI INTERNAL INTERFACE REQUIREMENTS

Section 3.1 shows the relationship between the APM CSCI and its four CSCs APMINIT, APMSTEP, XOINIT, and XOSTEP. The required internal interface between these four CSCs and the APM CSCI is left to the designer. However, Table 7 should be used as a guide to the required internal interfaces in the CSCI.

3.4 CSCI INTERNAL DATA REQUIREMENTS

The APM CSCI takes full advantage of Fortran 95 features, utilizing allocatable arrays for all internal and input arrays. The external CSCI designer must correctly allocate and initialize all arrays necessary for input to the APM CSCI.

Due to the computational intensity of the APM CSCI, it may not be necessary or desirable to use the extreme capability of the APM CSCI for all applications. The variables n_{rout} and n_{zout} refer to the desired number of range and height output points for any one particular application, and will be specified when the APMINIT CSC is called.

One of the parameters returned to the external application from the APMINIT CSC is i_{error}, which allows for greater flexibility in how input data are handled within the external application.

Table 6 lists all possible errors that can be returned.

Table 6. APMINIT SU returned error definitions.

i_{error}	**Definition**
-5	Frequency input must be greater than or equal to 2 MHz.
-6	Last range in terrain profile is less than r_{max}. Will only return this error if *lerr6* set to '.true.'.
-7	Specified cut-back angles (for user-defined height finder antenna pattern) are not increasing.
-8	h_{max} is less than maximum height of terrain profile.
-9	Antenna height with respect to mean sea level is greater than maximum height h_{max}.
-10	Beamwidth is less than or equal to zero for directional antenna pattern.
-11	Number of antenna pattern or power reduction factors and angles is less than or equal to 1. For i_{pat} = 6, n_{facs} must be at least 1; for i_{pat} = 7, n_{facs} must be at least 2.
-12	Range of last environment profile given (for range-dependent case) is less than r_{max}. Will only return this error if *lerr12* set to '.true.'.
-13	Height of first level in any user-specified refractivity profile is greater than 0. First height must be at mean sea level (0.0) or < 0.0 if below mean sea level.
-14	Last gradient in any environment profile is negative.
-17	Range points of terrain profile are not increasing.
-18	First range value in terrain profile is not 0.
-21	Clutter calculations are specified but no transmitter power has been provided.
-22	Clutter calculations are specified but no pulse length has been provided.
-23	Clutter calculations are specified, but no horizontal beamwidth has been provided.
-24	Clutter calculations are desired over terrain or for frequencies less than 1 GHz, but no γc values have been specified.

Table 6. APMinit SU returned error definitions. (continued)

i_{error}	**Definition**
-25	Specified only the PE model to be used but did not specify maximum propagation angle th_{max}.
-26	Clutter calculations are specified with the propagation path partly or entirely, over water but did not specify a wind speed.
-41	Transmitter height is less than 1.5 meters.
-42	Minimum height input by user, h_{min}, is greater than maximum height, h_{max}.
-43	Transform size is greater than 2^{30}.
-44	Combination of frequency and antenna beamwidth results in antenna physically below the surface. Increase frequency or beamwidth for valid combination.
-45	Wind speed specified is greater than the maximum allowed for the specified frequency.
-100	Error in terrain ray trace (*contact the APM CSCI developers if this occurs*)
115	*WARNING*: Antenna height with respect to mean sea level is greater than the last height in the refractivity profile at the source.

The logical variables *lerr6* and *lerr12*, when set to '.false.', allow the external application to bypass their associated errors, as these are not critical to the operation of the APM CSCI.

The APM CSCI provides propagation loss and propagation factor for all heights and ranges when running in a full hybrid mode. When running in a partial hybrid mode, it provides propagation loss and factor for all heights, but not necessarily for all angles. Refer to Section 3.1 for environmental conditions under which each execution mode is automatically selected.

Absorption by atmospheric gases (oxygen and water vapor) may be important to some applications of the APM CSCI and is controlled by specifying a non-zero value for the absolute humidity, abs_{hum}, and the surface air temperature, t_{air}, or likewise, by specifying a non-zero value for the gaseous absorption attenuation rate, γ_a.

A particular application of the APM CSCI may or may not require the consideration of troposcatter effects within the propagation loss/factor calculations. For example, a radar evaluation most likely would not be influenced by troposcatter; while an ESM evaluation would. APM has the feature of including or not including the troposcatter calculation by setting a logical flag called T_{ropo}. Setting this flag to '.false.' would omit the calculation. Setting this flag to '.true.' would include the calculation. For the APM CSCI implementation within the external coverage and loss diagram applications, T_{ropo} must be set to '.true.' so as to include the calculation.

APM also has the added capability to account for rough sea surface effects. Specifying a wind speed and a corresponding range will produce forward scatter results based on the Philips ocean-wave model for the root-mean-squared (rms) wave height and the Miller–Brown reflection coefficient reduction factor. The capability also exists to allow variable wind speeds with range.

APM, by default, will run in an "automatic" mode in which, depending upon user-specified inputs, will choose the appropriate sub-models to use for a particular application. However, by setting the logical flag PE_{flag} to '.true.' APM will be forced to use only the PE sub-model for a particular external application. By default, this flag is set to '.false.'. If this flag is '.true.' then the visible portion of the maximum PE propagation angle, th_{max} (i.e., the maximum propagation angle the PE algorithm will accommodate in the field calculations), and the parameter, r_{mult}, must be specified. By default, r_{mult} is equal to 1; however, th_{max} does not have a default value and must be explicitly defined. The parameter r_{mult} is a range step multiplier, allowing the user to vary the PE range step from the default calculated.

Use this option with caution, as you must have some basic knowledge of PE algorithms and how they work to input proper combinations of maximum calculation angles and range steps for a given frequency. *When using this option, most error checking is bypassed and parameter limits can be over-ridden. Erroneous field values may result if a poorly chosen combination of th_{max} and r_{mult} are used.*

APM Ver. 2.1.04 can determine and provide direct and reflected propagation angles, as well as the propagation factor from direct and reflected rays, to the main calling program. Note that these quantities are obtained only from the FE and RO sub-models in APM. It does not compute the angles and propagation factors for the separate rays within the split-step PE and XO sub-models, but does provide the resultant propagation angle and factor within these regions. This information is returned if the logical flag *lang* is set to '.true.', however, do not enable this feature if any portion of the propagation path is over land. The computation is valid only when the propagation path is entirely over water.

3.5 ADAPTATION REQUIREMENTS

3.5.1 Environmental Radio Refractivity Field Data Elements

The radio-refractivity field, i.e., the profiles of modified refractivity (M-units) versus height, must consist of vertical piece-wise linear profiles specified by couplets of height in meters with respect to mean sea level and M-units at multiple arbitrary ranges. All vertical profiles must contain the same number of vertical data points and be specified such that each numbered data point corresponds to like-numbered points (i.e., features) in the other profiles. The first numbered data point of each profile must correspond to a height of zero mean sea level and the last numbered data point must

correspond to a height such that the modified refractivity for all greater heights is well represented by extrapolation using the two highest profile points specified.

With the inclusion of terrain and allowing the terrain profile to fall below mean sea level, refractivity profiles can also be provided in which the first level is less than 0 (or below mean sea level). For a terrain profile that falls below mean sea level at some point, the assumption is that the minimum height may be less than the first height in any refractivity profile specified. Therefore, an extrapolation flag, i_{extra}, must be specified to indicate how the APM CSCI should extrapolate from the first refractivity level to the minimum height along the terrain profile. Setting i_{extra} to 0 will cause the APM CSCI to extrapolate to the minimum height using a standard atmosphere gradient; setting i_{extra} to 1 will cause the APM CSCI to extrapolate to the minimum height using the gradient determined from the first two levels of the refractivity profile.

Within each profile, each numbered data point must correspond to a height greater than or equal to the height of the previous data point. Note that this requirement allows for a profile containing redundant data points. Note also that all significant features of the refractivity profiles must be specified, even if they are above the maximum output height specified for a particular application of APM.

The external CSCI application designer and the external operator share responsibility for determining appropriate environmental inputs. For example, a loss diagram may be used to consider a surface-to-surface radar detection problem. Since the operator is interested in surface-to-surface, he may truncate the profile assuming that effects from elevated ducting conditions are negligible. It may be however, that the elevated duct does indeed produce a significant effect. The operator should insure therefore, that the maximum height of the profile allows for the inclusion of all significant refractive features.

This specification allows a complicated refractivity field to be described with a minimum of data points. For example, a field in which a single trapping layer linearly descends with increasing range can be described with just two profiles containing only four data points each, frame (a) of Figure 7. In the same manner, other evolutions of refractive layers may be described. Frames (b) and (c) of Figure 7 show two possible scenarios for the development of a trapping layer. The scenario of choice is the one that is consistent with the true thermodynamical and hydrological layering of the atmosphere.

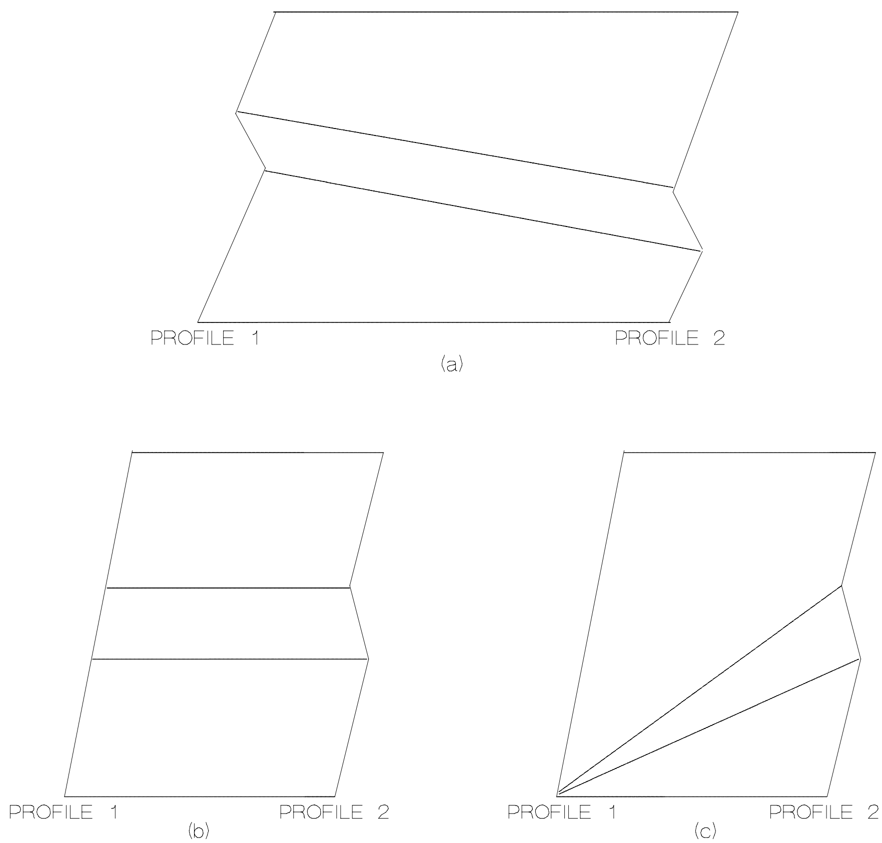

Figure 7. Idealized M-unit profiles (solid) and lines of interpolation (dashed).

Two external implementation data variables applicable to the external application operator and the calling application designer are r_{max}, the maximum APM CSCI output range, and h_{max}, the maximum APM CSCI output height. These two parameters are required by the APM CSCI to determine the horizontal and vertical resolution, respectively, for internal range and height calculations based on the current values of n_{rout} and n_{zout}. Any value of r_{max} and h_{max} is allowed for the convenience of the external application operator and the calling application designer, provided $r_{max} \geq 5$ km, and $h_{max} \geq 100$ m. For example, the external application operator may desire a coverage diagram that extends to a range of 500 km. In addition to accommodating the desires of the operator, specification of such a convenient maximum range eases the burden for the application designer in determining incremental tick marks for the horizontal axis of the display.

Provided the value of the parameter *lerr12* is set to '.false.', if the furthest environment profile range is less than r_{max}, the APM CSCI will automatically create an environment profile at r_{max} equal to the last profile specified, making the environment homogeneous from the range of the last profile specified to r_{max}. For example, a profile is input with an accompanying range of 450 km. If the external application operator

chooses an r_{max} of 500 km, the APM CSCI will continue propagation loss/factor calculations to 500 km, keeping the refractivity environment homogeneous from 450 to 500 km.

If *lerr12* is set to '.true.' and the furthest environment profile range is less than r_{max}, then an error will be returned in i_{error} from the APMINIT CSC, which allows the external CSCI application designer greater flexibility in how environment data are handled.

3.5.2 Terrain Profile Data Element

The terrain profile must consist of linear piece-wise segments specified as range/height pairs. All range values must be increasing, and the first terrain height value must be at range zero. General ground composition types can be specified (Table 4), along with corresponding ranges over which the ground type is to be applied. If ground type "User Defined" is specified ($igrnd_i$ = 7), then numeric values of relative permittivity and conductivity must be given. If horizontal antenna polarization is specified, and if running a smooth surface case, the APM CSCI will assume perfect conductivity for the entire terrain profile and will ignore any information regarding ground composition. If vertical antenna polarization is specified, or if performing rough surface calculations, then information regarding ground composition must also be specified. If wind speed has been provided, then rough surface calculations will also be performed.

The maximum height, h_{max}, must always be greater than the minimum height, h_{min}, by at least 100 m. Also, a value of h_{max} must be given such that it is larger than the maximum elevation height along a specified terrain profile.

If *lerr6* is set to '.false.' and the furthest range point in the terrain profile is less than r_{max}, the APM CSCI will automatically create a height/range pair as part of the terrain profile at r_{max} with elevation height equal to the last height specified in the profile, making the terrain profile flat from the range of the last profile point specified to r_{max}. For example, a terrain profile is input where the last height/range pair is 50 m high with an accompanying range of 95 km. If the external application operator chooses an r_{max} of 100 km, the APM CSCI will continue propagation loss/factor calculations to 100 km, keeping the terrain profile flat from 95 to 100 km with an elevation height of 50 m.

If *lerr6* is set to '.true.' and the furthest range point is less than r_{max}, then an error is returned in i_{error} from the APMINIT SU, which allows the external CSCI application designer greater flexibility in how terrain data is handled.

3.6 SECURITY AND PRIVACY REQUIREMENTS

The security and privacy requirements are the same as those required by the target employing the external CSCI.

3.7 CSCI ENVIRONMENTAL REQUIREMENTS

The APM CSCI must operate in the same hardware and software environments that the target employing the external CSCI operates.

3.8 COMPUTER RESOURCE REQUIREMENTS

Section 3.1.2.5 describes requirements for a Discrete Sine/Cosine Fast-Fourier Transform (DRST) SU. However, other sine FFT routines are available in the commercial market, and such a sine FFT may already be available within another external CSCI. The selection of which FFT ultimately used by APM CSCI is left to the application designer, as every sine FFT will have hardware and/or software performance impacts.

3.9 SOFTWARE QUALITY FACTORS

The primary required quality factors can be divided into the three categories: design, performance, and adaptation.

The quality factors for the design category should include correctness, maintainability, and verifiability. Correctness describes the extent to which the APM CSCI conforms to its requirements and is determined from the criteria of completeness, consistency, and/or traceability. Maintainability specifies the effort required to locate and fix an error in the APM CSCI. Maintainability is determined from the criteria of consistency, modularity, self-descriptiveness (self-documentation), and/or simplicity. Verifiability characterizes the effort required to test the APM CSCI to ensure that it performs its intended function. Verifiability is determined from the criteria of modularity, self-descriptiveness, and/or simplicity.

The quality factor for the performance category is reliability, which depicts the confidence that can be placed in the APM CSCI calculations. Reliability is determined from the criteria of accuracy, anomaly management, auditability, consistency, and/or simplicity.

The quality factors for the adaptation category are portability and reusability. Portability determines how easy it is to transport the APM CSCI from one hardware and/or software environment to another. Portability is determined from the criteria of application independence, modularity, and/or self-descriptiveness. Reusability illustrates how easy it is to convert the APM CSCI (or parts of the CSCI) for use in another application. Reusability is determined from the criteria of application independence, document accessibility, functional scope, generality, hardware independence, modularity, simplicity, self-descriptiveness, and/or system clarity.

Section A.A.1 defines the software quality criteria.

Only the software quality criteria of completeness, consistency, and traceability can be analyzed. Their calculation is described in Section A.2. The other criteria must be determined by demonstration, test, or inspection.

3.10 DESIGN AND IMPLEMENTATION CONSTRAINTS

3.10.1 Implementation And Application Considerations

The calling external CSCI application will determine the employment of the APM CSCI. However, the intensive computational nature of the APM CSCI must be considered when designing an efficient calling application. For this reason, the APM CSCI should be designed with flexibility for various hardware suites and computer resource management considerations. As stated in Section 1, this APM CSCI applies only to a coverage and loss diagram application. The following highly recommended guidelines will aid in the design of a coverage or loss diagram application that will most efficiently employ the APM CSCI.

The APM CSCI propagation loss calculations are independent of any target or receiver considerations; therefore, for any EM emitter, one execution of the APM CSCI may be used to create both a coverage diagram and a loss diagram. Since both execution time and computer memory allocation should be a consideration when employing this model, it is most efficient and appropriate to execute the APM CSCI for a particular EM system/environmental/terrain combination before executing any application. The output of the APM CSCI would be stored in a file that would be accessed by multiple applications.

For example, the external application operator may desire a coverage diagram for one particular radar system. At the beginning of the coverage diagram application, a check would be made for the existence of a previously created APM CSCI output file appropriate for the EM system and environmental and terrain conditions. If such a file exists, the propagation loss values would be read from the file and used to create the coverage diagram. If the file does not exist, the APM CSCI would be executed to create one. As the APM CSCI is executing, its output could be routed simultaneously to a graphics display device and a file. This file could then be used in the loss diagram application, should the operator also choose it. Two distinct applications, therefore, are achieved with only one execution of the APM CSCI. Additionally, should the operator desire an individual coverage diagram for each of multiple targets, or a single coverage diagram illustrating radar detection of a low-flying missile superimposed on a coverage diagram illustrating his/her own radar's vulnerability as defined by the missile's ESM receiver, only a single execution of the APM CSCI would be required, thereby saving valuable computer resources.

3.10.2 Programming Language And Source Implementation

3.10.2.1 Programming Language

The ANSI Fortran 95 program language standard must be used in the development of the APM CSCI. This standard consists of the specifications of the language Fortran. With certain limitations, the syntax and semantics of the old International Standard commonly known as "FORTRAN 77" are contained entirely within this new International Standard. Therefore, any standard-conforming FORTRAN 77 program is standard, conforming under the Fortran 95 Standard. Note that the name of this language, Fortran, differs from that in FORTRAN 77 in that only the first letter is capitalized. The Overview section of the International Standard describes the major additions to FORTRAN 77 in this International Standard. Section 1.3 of the International Standard specifies the bounds of the Fortran language by identifying those items included and those items excluded. Section 1.4.1 describes the FORTRAN 77 compatibility of the International Standard with emphasis on four FORTRAN 77 features having different interpolations in the new International Standard. The International Standard provides facilities that encourage the design and the use of modular and reusable software.

Section 8.2 of the International Standard describes nine obsolescent features of FORTRAN 77 that are redundant and for which better methods are available in FORTRAN 77 itself. These nine obsolescent features should not be used. These obsolescent features are as follows:

1. **Arithmetic IF** - use the **IF** statement.

2. Real and double precision **DO** control variables and **DO** loop control expressions - use integer.

3. Shared **DO** termination and termination on a statement other than **END DO** or **CONTINUE** - use an **END DO** or a **CONTINUE** statement for each **DO** statement.

4. Branching to an **END IF** statement from outside its IF block - branch to the statement following the **END IF**.

5. Alternate return.

6. **PAUSE** statement.

7. **ASSIGN** and assigned **GO TO** statements.

8. Assigned **FORMAT** specifiers.

9. cH (nH) edit descriptor.

Remedies for the last five obsolescent features are described in Section 8.2 of the International standard.

3.10.2.2 Source Implementation

The Standards document by the Naval Oceanographic Office establishes a uniform standard for all software submitted by all contributors to them. It is recommended that the coding requirements set forth in Section 4 of that document be followed. Among these recommendations are:

1. Special non-ANSI features shall be avoided. Non-ANSI practices that are necessary must be documented in the code itself.

2. Maximum use should be made of existing commercially available FORTRAN callable libraries.

3. Programs shall be designed and coded using only five basic control structures - sequence of operations (assignment, add, ...), **IF THEN ELSE**, **DO WHILE**, **DO UNTIL**, and **CASE**.

4. Procedures or routines that make up a module shall not exceed an average of 100 executable statements per procedure or routine and shall not exceed a maximum of 200 executable statements in any procedure or routine.

5. Branching statements (**GO TO**s) shall only pass control to a statement that is in the same procedure or routine. Each **GO TO** must pass control only forward of its point of occurrence.

6. Naming conventions shall be uniform throughout the software. Program, subprogram, module, procedure, and data names shall be uniquely chosen to identify the applicable function performed. The naming convention for **COMMON** shall be consistent across the entire program.

7. Constants shall be defined not calculated (e.g., do no use *HALF = ½*, use *HALF = 0.5*)

8. Mixed-mode numerical operations should be avoided whenever possible. When determined to be necessary, the use shall be explicit (*FLOAT*, *FIX*, or in assignment statement) and completely described in comments.

9. Each component of the software shall have a prologue containing the name of the program, subprogram, or function and any version number; purpose; inputs; outputs; list of routines that call this routine; complete list of routines called including intrinsic functions such as *ABS* and *FLOAT*; glossary; and method.

10. To facilitate program comprehension, comment statements shall be used throughout the program code.

11. The use of the **EQUIVALENCE** statement shall be restricted to those where it either improves the readability of the code or the efficiency of the program. If the **EQUIVALENCE** statement is used, it must be fully documented in the prologue and inline comment statements.

12. No machine-dependent techniques are allowed, unless there is no other way of performing the task.

13. Initialize every variable before use.

14. Do not depend on the values of “local” variables computed on a previous call to a routine.

15. Program structural indentation shall be used to improve readability and clarity.

3.11 PERSONNEL-RELATED REQUIREMENTS

N/A.

3.12 TRAINING RELATED REQUIREMENTS

The employing target software personnel implementing this CSCI into the external CSCI will require training to become familiar with APM. This requirement should be met by this document and the companion Software Design Description (SDD) and Software Test Description (STD) documents.

3.13 OTHER REQUIREMENTS

None.

3.14 PRECEDENCE AND CRITICALITY OF REQUIREMENTS

The requirements presented in Sections 3.1 through 3.5 and Sections 3.8 through 3.10 have precedence over Sections 3.6, 3.7, 3.11, 3.12, and 3.13 and should be given equal weight.

4. QUALIFICATION PROVISIONS

N/A

5. REQUIREMENTS TRACEABILITY

5.1 SYSTEM TRACEABILITY

This section provides traceability of requirements between the APM CSCI and the external CSCI.

1. The APM CSCI environmental data requirements should be obtained from the environmental application or database within the external CSCI. The APM CSCI terrain data element requirements should be obtained from any desired terrain database within the external CSCI, however, it is up to the external CSCI to extract the terrain in the proper format for inputting to APM. The radar/communication system data element requirements should be obtained from the EM system database within the external CSCI.

2. The external CSCI requirement of propagation loss vs. range and height should be obtained from the APM CSCI.

5.2 DOCUMENTATION TRACEABILITY

This section provides the following types of traceability between the Software Requirements Specification (SRS), the Software Design Description (SDD), and the Software Test Description (STD):

1. Traceability between levels of requirements

2. Traceability between the software requirements and software design

3. Traceability between the software requirements and qualification test information obtained from the software testing

This traceability of the Advanced Propagation Model is presented in two tables. The first table, Table 7, presents the traceability between levels of SRS requirements. The second table (Table 137 in the SDD) presents the traceability between the software requirements and software design.

Table 7. Requirements traceability matrix for the SRS.

Software Requirements Specification		**Software Requirements Specification**	
SRS Requirement Name	SRS Paragraph Number	SRS Requirement Name	SRS Paragraph Number
CSCI Capability Requirements	3.1	Advance Propagation Initialization (APMINIT) CSC	3.1.1
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Allocate Arrays APM (ALLARRAY_APM) SU	3.1.1.1
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Allocate Array RO (ALLARRAY_RO) SU	3.1.1.3
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Allocate Array XORUF (XORUF) SU	3.1.1.4
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Alpha Impedance Initialization (ALN_INIT) SU	3.1.1.5
Alpha Impedance Initialization (ALN_INIT) SU	3.1.1.5	Get Alpha Impedance (GETALN) SU	3.1.1.13
Get Alpha Impedance(GETALN) SU	3.1.1.13	Current Wind (FN_CURWIND) Function	3.1.2.2
Get Alpha Impedance(GETALN) SU	3.1.1.13	Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Current Wind (FN_CURWIND) Function	3.1.2.2
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Dielectric Constant (FN_DIECON) Function	3.1.2.3
Get Alpha Impedance(GETALN) SU	3.1.1.13	Surface Impedance (SURFIMP) SU	3.1.2.23
Surface Impedance (SURFIMP) SU	3.1.2.23	Poly 4 (FN_POLY4) Function	3.1.1.20
Surface Impedance (SURFIMP) SU	3.1.2.23	Poly 5 (FN_POLY5) Function	3.1.1.21
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Dielectric Initialization (DIEINIT) SU	3.1.1.8
Advance Propagation Initialization (APMINIT) CSC	3.1.1	FFT Parameters (FFTPAR) SU	3.1.1.9

Table 7. Requirements traceability matrix for the SRS. (continued)

Software Requirements Specification		Software Requirements Specification	
SRS Requirement Name	SRS Paragraph Number	SRS Requirement Name	SRS Paragraph Number
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Fill Height Arrays (FILLHT) SU	3.1.1.10
Fill Height Arrays (FILLHT) SU	3.1.1.10	Trace to Output Range (TRACE_ROUT) SU	3.1.1.27
Fill Height Arrays (FILLHT) SU	3.1.1.10	Trace to Next Step (TRACE_STEP) SU	3.1.1.28
Trace to Next Step (TRACE_STEP) SU	3.1.1.28	Height Check (HTCHECK) SU	3.1.1.17
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Gaseous Absorption (GASABS) SU	3.1.1.11
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Get Effective Earth Radius Factor (GET_K) SU	3.1.1.12
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Get Angles (GETANGLES) SU	3.1.1.14
Get Angles (GETANGLES) SU	3.1.1.14	APM Status (APMSTATUS) SU	3.1.1.7
Get Angles (GETANGLES) SU	3.1.1.14	DOSHIFT SU	3.1.2.4
Get Angles (GETANGLES) SU	3.1.1.14	Free Space Range Step (FRSTP) SU	3.1.1.24
Free Space Range Step (FRSTP) SU	3.1.2.9	Fast Fourier Transform (FFT) SU	3.1.2.8
Fast Fourier Transform (FFT) SU	3.1.2.8	Discrete Sine/Cosine Transform (DRST) SU	3.1.2.5
Get Angles (GETANGLES) SU	3.1.1.14	Refractivity Interpolation (REFINTER) SU	3.1.2.18
Refractivity Interpolation (REFINTER) SU	3.1.2.18	Interpolate Profile (INTPROF) SU	3.1.1.18
Interpolate Profile (INTPROF) SU	3.1.1.18	Linear Interpolation (FN_PLINT) Function	3.1.2.14
Refractivity Interpolation (REFINTER) SU	3.1.2.18	Profile Reference (PROFREF) SU	3.1.1.22
Refractivity Interpolation (REFINTER) SU	3.1.2.18	Remove Duplicate Refractivity Levels (REMDUP) SU	3.1.1.24
Get Angles (GETANGLES) SU	3.1.1.14	RG Trace (RGTRACE) SU	3.1.1.25
RG Trace (RGTRACE) SU	3.1.1.25	Trace to Next Step (TRACE_STEP) SU	3.1.1.28

Table 7. Requirements traceability matrix for the SRS. (continued)

Software Requirements Specification		Software Requirements Specification	
SRS Requirement Name	SRS Paragraph Number	SRS Requirement Name	SRS Paragraph Number
Trace to Next Step (TRACE_STEP) SU	3.1.1.28	Height Check (HTCHECK) SU	3.1.1.17
Get Angles (GETANGLES) SU	3.1.1.14	Spectral Estimation (SPECEST) SU	3.1.2.22
Spectral Estimation (SPECEST) SU	3.1.2.22	Discrete Sine/Cosine Transform (DRST) SU	3.1.2.5
Get Angles (GETANGLES) SU	3.1.1.14	Trace to Output Range (TRACE_ROUT) SU	3.1.1.27
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Get Maximum Angle (GETTHMAX) SU	3.1.1.15
Get Maximum Angle (GETTHMAX) SU	3.1.1.15	FFT Parameters (FFTPAR) SU	3.1.1.9
Get Maximum Angle (GETTHMAX) SU	3.1.1.15	Trace to Output Range (TRACE_ROUT) SU	3.1.1.27
Advance Propagation Initialization (APMinit) CSC	3.1.1	Grazing Angle Interpolation (GRAZE_INT) SU	3.1.1.16
Grazing Angle Interpolation (GRAZE_INT) SU	3.1.1.16	Linear Interpolation (FN_PLINT) Function	3.1.2.14
Advance Propagation Initialization (APMinit) CSC	3.1.1	PE Initialization (PEINIT) SU	3.1.1.19
PE Initialization (PEINIT) SU	3.1.1.19	Allocate Array PE (ALLARRAY_PE) SU	3.1.1.2
PE Initialization (PEINIT) SU	3.1.1.19	Interpolate Profile (INTPROF) SU	3.1.1.18
PE Initialization (PEINIT) SU	3.1.1.19	Starter Field Initialization (XYINIT) SU	3.1.1.30
Starter Field Initialization (XYINIT) SU	3.1.1.30	Antenna Pattern (ANTPAT) SU	3.1.1.6
Starter Field Initialization (XYINIT) SU	3.1.1.30	Discrete Sine/Cosine Transform (DRST) SU	3.1.2.5
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Profile Reference (PROFREF) SU	3.1.1.22
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Refractivity Initialization (REFINIT) SU	3.1.1.23
Refractivity Initialization (REFINIT) SU	3.1.1.23	Profile Reference (PROFREF) SU	3.1.1.22

Table 7. Requirements traceability matrix for the SRS. (continued)

Software Requirements Specification		Software Requirements Specification	
SRS Requirement Name	SRS Paragraph Number	SRS Requirement Name	SRS Paragraph Number
Refractivity Initialization (REFINIT) SU	3.1.1.23	Remove Duplicate Refractivity Levels (RemDup) SU	3.1.1.24
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Remove Duplicate Refractivity Levels (RemDup) SU	3.1.1.24
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Terrain Initialization (TERINIT) SU	3.1.1.26
Advance Propagation Initialization (APMinit) CSC	3.1.1	Troposcatter Initialization (TROPOINIT) SU	3.1.1.29
Troposcatter Initialization (TROPOINIT) SU	3.1.1.29	Antenna Pattern (Antpat) SU	3.1.1.6
Troposcatter Initialization (TROPOINIT) SU	3.1.1.29	Get Effective Earth Radius Factor (GET_K) SU	3.1.1.12
CSCI Capability Requirements	3.1	Advance Propagation Model Step (APMSTEP) CSC	3.1.2
Advance Propagation Model Step (APMSTEP) CSC	3.1.2	Flat-Earth Direct Ray (FEDR) SU	3.1.2.6
Flat-Earth Direct Ray (FEDR) SU	3.1.2.6	Antenna Pattern (Antpat) SU	3.1.1.6
Advance Propagation Model Step (APMSTEP) CSC	3.1.2	Flat-Earth Model (FEM) SU	3.1.2.7
Flat-Earth Model (FEM) SU	3.1.2.7	Antenna Pattern (Antpat) SU	3.1.1.6
Flat-Earth Model (FEM) SU	3.1.2.7	Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.16	Current Wind (FN_CURWIND) Function	3.1.2.2
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Dielectric Constant (FN_DIECON) Function	3.1.2.3
Advance Propagation Model Step (APMSTEP) CSC	3.1.2.10	Parabolic Equation Step (PESTEP) SU	3.1.2.16
Parabolic Equation Step (PESTEP) SU	3.1.2.16	Calculate Propagation Loss (CALCLOS) SU	3.1.2.1
Calculate Propagation Loss (CALCLOS) SU	3.1.2.1	Get Propagation Factor (FN_GETPFAC) Function	3.1.2.11
Calculate Propagation Loss (CALCLOS) SU	3.1.2.1	Linear Interpolation (FN_PLINT) Function	3.1.2.14

Table 7. Requirements traceability matrix for the SRS. (continued)

Software Requirements Specification		**Software Requirements Specification**	
SRS Requirement Name	SRS Paragraph Number	SRS Requirement Name	SRS Paragraph Number
Calculate Propagation Loss (CALCLOS) SU	3.1.2.1	Troposcatter (TROPOSCAT) SU	3.1.2.24
Troposcatter (TROPOSCAT) SU	3.1.2.24	Get Troposcatter Loss (FN_GET_TLOSS) Function	3.1.2.13
Get Troposcatter Loss (FN_GET_TLOSS) Function	3.1.2.13	Antenna Pattern (ANTPAT) SU	3.1.1.6
Parabolic Equation Step (PESTEP) SU	3.1.2.16	DOSHIFT SU	3.1.2.4
Parabolic Equation Step (PESTEP) SU	3.1.2.16	Free Space Range Step (FRSTP) SU	3.1.1.24
Free Space Range Step (FRSTP) SU	3.1.1.24	Fast-Fourier Transform (FFT) SU	3.1.2.8
Fast-Fourier Transform (FFT) SU	3.1.2.8	Discrete Sine/Cosine Transform (DRST) SU	3.1.2.5
Parabolic Equation Step (PESTEP) SU	3.1.2.16	FZLIM SU	3.1.2.10
FZLIM SU	3.1.2.10	Get Propagation Factor (FN_GETPFAC) Function	3.1.2.11
FZLIM SU	3.1.2.10	Save Profile (SAVEPRO) SU	3.1.2.21
FZLIM SU	3.1.2.10	Spectral Estimation (SPECEST) SU	3.1.2.22
Spectral Estimation (SPECEST) SU	3.1.2.22	Discrete Sine/Cosine Transform (DRST) SU	3.1.2.5
Parabolic Equation Step (PESTEP) SU	3.1.2.16	Get Alpha Impedance (GETALN) SU	3.1.1.13
Get Alpha Impedance (GETALN) SU	3.1.1.13	Current Wind (FN_CURWIND) Function	3.1.2.2
Get Alpha Impedance (GETALN) SU	3.1.1.13	Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Current Wind (FN_CURWIND) Function	3.1.2.2
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Dielectric Constant (FN_DIECON) Function	3.1.2.3
Get Alpha Impedance(GETALN) SU	3.1.1.13	Surface Impedance (SURFIMP) SU	3.1.2.23

Table 7. Requirements traceability matrix for the SRS. (continued)

Software Requirements Specification		**Software Requirements Specification**	
SRS Requirement Name	SRS Paragraph Number	SRS Requirement Name	SRS Paragraph Number
Surface Impedance (SURFIMP) SU	3.1.2.23	Poly 4 (FN_POLY4) Function	3.1.1.20
Surface Impedance (SURFIMP) SU	3.1.2.23	Poly 5 (FN_POLY5) Function	3.1.1.21
Parabolic Equation Step (PESTEP) SU	3.1.2.16	Mixed Fourier Transform (MIXEDFT) SU	3.1.2.15
Mixed Fourier Transform (MIXEDFT) SU	3.1.2.15	Free Space Range Step (FRSTP) SU	3.1.1.24
Free Space Range Step (FRSTP) SU	3.1.1.24	Fast-Fourier Transform (FFT) SU	3.1.2.8
Fast-Fourier Transform (FFT) SU	3.1.2.8	Discrete Sine/Cosine Transform (DRST) SU	3.1.2.5
Parabolic Equation Step (PESTEP) SU	3.1.2.16	Refractivity Interpolation (REFINTER) SU	3.1.2.18
Refractivity Interpolation (REFINTER) SU	3.1.2.18	Interpolate Profile (INTPROF) SU	3.1.1.18
Interpolate Profile (INTPROF) SU	3.1.1.18	Linear Interpolation (FN_PLINT) Function	3.1.2.14
Refractivity Interpolation (REFINTER) SU	3.1.2.18	Profile Reference (PROFREF) SU	3.1.1.22
Refractivity Interpolation (REFINTER) SU	3.1.2.18	Remove Duplicate Refractivity Levels (REMDUP) SU	3.1.1.24
Advance Propagation Model Step (APMSTEP) CSC	3.1.2	Ray Optics Loss (ROLOSS) SU	3.1.2.20
Ray Optics Loss (ROLOSS) SU	3.1.2.20	Ray Optics Calculation (ROCALC) SU	3.1.2.19
Ray Optics Calculation (ROCALC) SU	3.1.2.19	Antenna Pattern (ANTPAT) SU	3.1.1.6
Ray Optics Calculation (ROCALC) SU	3.1.2.19	Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Current Wind (FN_CURWIND) Function	3.1.2.2
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Dielectric Constant (FN_DIECON) Function	3.1.2.3

Table 7. Requirements traceability matrix for the SRS. (continued)

Software Requirements Specification		Software Requirements Specification	
SRS Requirement Name	SRS Paragraph Number	SRS Requirement Name	SRS Paragraph Number
Ray Optics Calculation (ROCALC) SU	3.1.2.19	Ray Trace (RAYTRACE) SU	3.1.2.17
CSCI Capability Requirements	3.1	Extended Optics Initialization (XOINIT) CSC	3.1.3
Extended Optics Initialization (XOINIT) CSC	3.1.3	APM Clean (APMCLEAN) SU	3.1.3.1
APM Clean (APMCLEAN) SU	3.1.3.1	Discrete Sine/Cosine (DRST) SU	3.1.3.1
Extended Optics Initialization (XOINIT) CSC	3.1.3	Clutter-to-Noise (CLUTTER) SU	3.1.3.2
Clutter-to-Noise (CLUTTER) SU	3.1.3.2	GIT Initialization (GIT_INIT) SU	3.1.3.5
GIT Initialization (GIT_INIT) SU	3.1.3.5	Current Wind (FN_CURWIND) Function	3.1.2.2
Clutter-to-Noise (CLUTTER) SU	3.1.3.2	Standard Propagation Model Initialization (SPM_INIT) SU	3.1.3.11
Clutter-to-Noise (CLUTTER) SU	3.1.3.2	Standard Propagation Model (SPM) SU	3.1.3.12
Standard Propagation Model (SPM) SU	3.1.3.12	Diffraction Loss (FN_DLOSS) Function	3.1.3.3
Standard Propagation Model (SPM) SU	3.1.3.12	GofZ (FN_GOFZ) Function	3.1.3.6
Standard Propagation Model (SPM) SU	3.1.3.12	Optical Region Limit (OPLIMIT) SU	3.1.3.8
Optical Region Limit (OPLIMIT) SU	3.1.3.8	Get Theta (GETTHETA) SU	3.1.3.4
Get Theta (GETTHETA) SU	3.1.3.8	Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Current Wind (FN_CURWIND) Function	3.1.2.2
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Dielectric Constant (FN_DIECON) Function	3.1.2.3
Optical Region Limit (OPLIMIT) SU	3.1.3.8	R1 Iteration (R1ITER) SU	3.1.2.3
R1 Iteration (R1ITER) SU	3.1.2.3	Get Theta (GETTHETA) SU	3.1.3.4

Table 7. Requirements traceability matrix for the SRS. (continued)

Software Requirements Specification		Software Requirements Specification	
SRS Requirement Name	SRS Paragraph Number	SRS Requirement Name	SRS Paragraph Number
Get Theta (GETTHETA) SU	3.1.3.4	Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Current Wind (FN_CURWIND) Function	3.1.2.2
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Dielectric Constant (FN_DIECON) Function	3.1.2.3
Standard Propagation Model (SPM) SU	3.1.3.12	Optical Difference (OPTICF) SU	3.1.3.9
Optical Difference (OPTICF) SU	3.1.3.9	Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Current Wind (FN_CURWIND) Function	3.1.2.2
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Dielectric Constant (FN_DIECON) Function	3.1.2.3
Extended Optics Initialization (XOINIT) CSC	3.1.3	Mean Filter (MEANFILT) SU	3.1.3.7
CSCI Capability Requirements	3.1	Extended Optics Step (XOSTEP) CSC	3.1.4
Extended Optics Step (XOSTEP) CSC	3.1.4	APM Clean (APMCLEAN) SU	3.1.3.1
APM Clean (APMCLEAN) SU	3.1.3.1	Discrete Sine/Cosine Transform (DRST) SU	3.1.3.1
Extended Optics Step (XOSTEP) CSC	3.1.4	Extended Optics (EXTO) SU	3.1.4
Extended Optics (EXTO) SU	3.1.4	Linear Interpolation (FN_PLINT) Function	3.1.2.14
Extended Optics (EXTO) SU	3.1.4	Troposcatter (TROPOSCAT) SU	3.1.2.24
Troposcatter (TROPOSCAT) SU	3.1.2.24	Get Troposcatter Loss (FN_GET_TLOSS) Function	3.1.2.13
Get Troposcatter Loss (FN_GET_TLOSS) Function	3.1.2.13	Antenna Pattern (ANTPAT) SU	3.1.1.6
Extended Optics Step (XOSTEP) CSC	3.1.4	Flat-Earth Model (FEM) SU	3.1.2.7
Flat-Earth Model (FEM) SU	3.1.2.7	Antenna Pattern (ANTPAT) SU	3.1.1.6

Table 7. Requirements traceability matrix for the SRS. (continued)

Software Requirements Specification		Software Requirements Specification	
SRS Requirement Name	SRS Paragraph Number	SRS Requirement Name	SRS Paragraph Number
Flat-Earth Model (FEM) SU	3.1.2.7	Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Current Wind (FN_CURWIND) Function	3.1.2.2
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Dielectric Constant (FN_DIECON) Function	3.1.2.3
Extended Optics Step (XOSTEP) CSC	3.1.4	Ray Optics Loss (ROLOSS) SU	3.1.2.20
Ray Optics Loss (ROLOSS) SU	3.1.2.20	Ray Optics Calculation (ROCALC) SU	3.1.2.19
Ray Optics Calculation (ROCALC) SU	3.1.2.19	Antenna Pattern (ANTPAT) SU	3.1.1.6
Ray Optics Calculation (ROCALC) SU	3.1.2.19	Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Current Wind (FN_CURWIND) Function	3.1.2.2
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Dielectric Constant (FN_DIECON) Function	3.1.2.3
Ray Optics Calculation (ROCALC) SU	3.1.2.19	Ray Trace (RAYTRACE) SU	3.1.2.17
CSCI Capability Requirements	3.1	Return Grazing Angle (RET_GRAZE) CSC	3.1.5
CSCI Capability Requirements	3.1	CSCI External Interface Requirements	3.2
CSCI Capability Requirements	3.1	CSCI Internal Interface Requirements	3.3
CSCI Capability Requirements	3.1	CSCI Internal Data Requirements	3.4
CSCI Capability Requirements	3.1	Adaptation Requirements	3.5
CSCI Capability Requirements	3.1	Security and Privacy Requirements	3.6
CSCI Capability Requirements	3.1	CSCI Environmental Requirements	3.7
CSCI Capability Requirements	3.1	Computer Resource Requirements	3.8

Table 7. Requirements traceability matrix for the SRS. (continued)

Software Requirements Specification		**Software Requirements Specification**	
SRS Requirement Name	SRS Paragraph Number	SRS Requirement Name	SRS Paragraph Number
CSCI Capability Requirements	3.1	Software Quality Factors	3.9
CSCI Capability Requirements	3.1	Design And Implementation Constraints	3.10
Design And Implementation Constraints	3.10	Implementation and Application Considerations	3.10.1
Design And Implementation Constraints	3.10	Programming Language And Source Code Implementation	3.10.2
Programming Language And Source Code Implementation	3.10.2	Programming Language	3.10.2.1
Programming Language And Source Code Implementation	3.10.2	Source Implementation	3.10.2.2
CSCI Capability Requirements	3.1	Personnel-Related Requirements	3.11
CSCI Capability Requirements	3.1	Training Related Requirements	3.12
CSCI Capability Requirements	3.1	Other Requirements	3.13
CSCI Capability Requirements	3.1	Precedence and Criticality of Requirements	3.14

6. NOTES

Table 8 is a glossary of acronyms and abbreviations used within this document. Table 9 is a glossary of Fortran terms used within this document.

Table 8. Acronyms and abbreviations.

Term	Definition
ANSI	American National Standards Institute
APM	Advanced Propagation Model
cB	centibel
CSC	Computer Software Component
CSCI	Computer Software Configuration Item
dB	decibel
EM	Electromagnetic
FFT	Fast-Fourier Transform
Fortran	Formula Translation
km	kilometers
m	meters
M	modified refractivity units
MHz	megahertz
N/A	not applicable
PE	Parabolic Equation
p-space	phase (angle) space
rad	radians
SDD	Software Design Description
SRS	Software Requirements Specification
STD	Software Test Description
SU	Software Unit
z-space	height space

Table 9. Fortran terms.

Term	Action or Definitions
ABS	Absolute value function
Arithmetic IF	Transfers control to one of three statement labels, depending on the vallue of *expression*
ASSIGN	Assigns the value of a format or statement label to an integer variable
CASE	Marks the beginning of a block of statements executed if an item in a list of expressions matches the test expressions
COMMON	Allows two or more program units to directly share variables without having to pass them as arguments
CONTINUE	Does not have any effect
DO	Repeatedly executes the statements following the DO statement through the statement which marks the end of the loop
DO WHILE	Executes a block of statements repeatedly while a logical condition remains true
END DO	Terminates a DO or DO WHILE loop
END IF	Terminates a block of IF statements
EQUIVALENCE	Causes two or more variables or arrays to occupy the same memory location
FIX	Data type conversion function
FLOAT	Data type conversion function
FORMAT	Sets the format in which data are written to or read from a file
GO TO	Transfers execution to the statement label assigned to variable
IF	If expression is true, statement is executed; if expression is false, program execution continues with the next executable statement
IF THEN ELSE	If expression is true, statements in the IF block are executed; if expression is false, control is transferred to the next ELSE, ELSE IF, or END IF statement at the same IF level
PAUSE	Temporarily suspends program execution and allows you to execute operating system commands during the suspension

APPENDIX A

A.1 DEFINITIONS OF QUALITY FACTOR CRITERIA

The criteria for judging the quality factors of Section 3.9 have the following definitions:

1. Accuracy. The precision of computations and control

2. Anomaly management. The degree to which the program detects failure in order to maintain consistency

3. Application independence. The degree to which the program is independent of nonstandard programming language features, operating system characteristics, and other environmental constraints

4. Auditability. The ease with which conformance to standards can be checked

5. Completeness. The degree to which full implementation of required function has been achieved

6. Consistency. The use of uniform design and documentation techniques throughout the software development project

7. Document accessibility. The availability of documents describing the program components

8. Functional scope. The generality of the feature set and capabilities of the program

9. Generality. The breadth of potential application of program components

10. Hardware independence. The degree to which the software is decoupled from the hardware on which it operates

11. Modularity. The functional independence of program components

12. Self-descriptiveness. The degree to which the source code provides meaningful documentation

13. Simplicity. The degree to which a program can be understood without difficulty

14. System clarity. The ease for which the feature set and capabilities of the system can be determined

15. Traceability. The ability to trace a design representation or actual program component back to requirements

A.2 SOFTWARE QUALITY METRICS

A.2.1 Completeness Criteria

The criteria completeness can be determined from the metric:

1. no ambiguous references (input, function, output)

2. all data references defined

3. all referenced functions defined

4. all defined functions used

5. all conditions and processing defined for each decision point

6. all defined and referenced calling sequences parameters agree

7. all problem reports resolved

8. design agrees with requirements

9. code agrees with design

10. (score 0 for any untrue statement; 1 otherwise)

11. metric value = SUM (scores)/9

A.2.2 Consistency Criteria

The criteria consistency can be determined from the metric: number of modules violating the design standard divided by the number of modules.

A.2.3 Traceability Criteria

The criteria traceability can be determined from the metric: number of itemized requirements traced divided by the total number of requirements.

SOFTWARE DESIGN DESCRIPTION
FOR THE
ADVANCED PROPAGATION MODEL CSCI
(Version 2.1.04)

20 December 2006

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SCOPE

1.1 IDENTIFICATION

The Advanced Propagation Model (APM) Version 2.1.04 computer software configuration item (CSCI) calculates range-dependent electromagnetic (EM) system propagation loss within a heterogeneous atmospheric medium over variable terrain, where the radio-frequency index of refraction is allowed to vary vertically and horizontally, also accounting for terrain effects along the path of propagation.

1.2 SYSTEM OVERVIEW

The APM CSCI model calculates propagation loss values as EM energy propagates through a laterally heterogeneous atmospheric medium where the index of refraction is allowed to vary both vertically and horizontally, also accounting for terrain effects along the path of propagation. Numerous external applications require EM-system propagation loss values. The APM model described by this document may be applied to two external applications, one which displays propagation loss on a range versus height scale (commonly referred to as a coverage diagram) and one which displays propagation loss on a propagation loss versus range/height scale (commonly referred to as a loss diagram).

1.3 DOCUMENT OVERVIEW

This document describes the design of the APM CSCI. An overview of the input software requirements is presented together with an overview of the CSCI design architecture and a detailed design description of each component of the CSCI.

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3. CSCI-WIDE DESIGN DECISIONS

The required APM CSCI propagation model is a range-dependent hybrid model that uses the complimentary strengths of Ray Optics (RO) and Parabolic Equation (PE) techniques to calculate propagation loss in range and altitude.

The atmospheric volume is divided into regions that lend themselves to the application of the various propagation loss calculation methods. Figure 1 illustrates these regions.

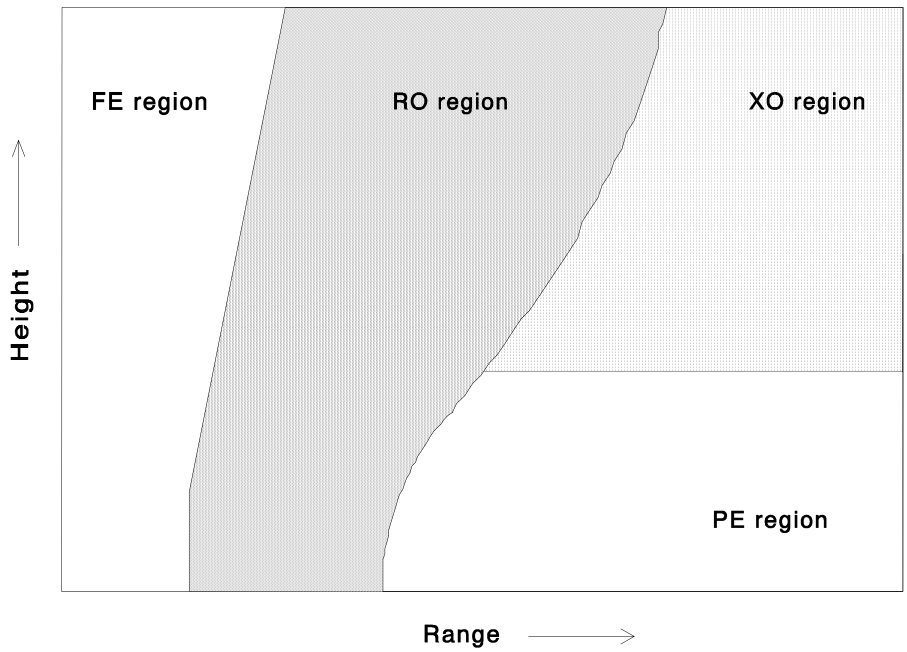

Figure 1. APM calculation regions.

For antenna elevation angles above 5º or for ranges less than approximately 2.5 km, a flat-earth (FE) (RO) model is used. In this region, only receiver height is corrected for average refraction and earth curvature.

Within the RO region (as defined by a limiting ray), propagation loss is calculated from the mutual interference between the direct-path and surface-reflected ray components using the refractivity profile at zero range. Full account is given to focusing or de-focusing along direct and reflected ray paths and to the integrated optical path length difference between the two ray paths, to give precise phase difference, and, hence, accurate coherent sums for the computation of propagation loss.

For the low-altitude region beyond the RO region, a PE approximation to the Helmholtz full-wave equation is employed. The PE model allows for range-dependent refractivity profiles and variable terrain along the propagation path and uses a split step Fourier method for the solution of the PE. The PE model is run in the minimum region required to contain all terrain and trapping layer heights.

For the area beyond the RO region but above the PE region, an extended optics region (XO) is defined. Within the XO region, RO methods that are initialized by the PE solution from below, are used.

APM will run in three "execution" modes, depending on environmental inputs. APM will use the FE, RO, XO, and PE models if the terrain profile is flat for the first 2.5 km and if the antenna height is less than or equal to 100 m. It will use only the XO and PE models if the terrain profile is *not* flat for the first 2.5 km and if the antenna height is

less than or equal to 100 m. For applications in which the antenna height is greater than 100 meters, a combination of FE and PE methods are used. The FE model is used for all propagation angles greater than ±5º from the source and the PE model is used for angles within ±5º. By default, APM will automatically choose which mode of operation it will use for a specified set of inputs. However, the ability to run only the PE model for any case is allowed by setting a logical flag upon input. APM will automatically run only the PE algorithm for frequencies less than 50 MHz, regardless of the logical flag set by the user.

The APM CSCI allows for horizontal and vertical antenna polarization, finite conductivity based on user-specified ground composition and dielectric parameters, and the complete range of EM system parameters and most antenna patterns required by various external applications. APM also allows for gaseous absorption effects in all sub-models and computes troposcatter losses within the diffraction region and beyond.

The APM CSCI is divided into 5 main computer software components (CSC) and 67 additional software units (SU). The first CSC, the APMINIT CSC, interfaces with various SUs for the complete initialization of the APM CSCI. The second CSC, the APMSTEP CSC, advances the entire APM CSCI algorithm one output range step, referencing various SUs to calculate the propagation loss at the current output range. The Extended Optics Initilization (XOINIT) CSC initializes the range, height, and angle arrays in preparation for the Extended Optics Step (XOSTEP) CSC, and also computes and returns the surface clutter values if requested. The fourth CSC (XOSTEP) advances the APM CSCI algorithm one output step from the top of the PE calculation region to the maximum output height specified, referencing various SUs to calculate the propagation output range. Lastly, the RET_GRAZE CSC is used to return the grazing angles for use in other applications outside the APM CSCI for a specified set of environmental inputs and system parameters.

4. CSCI ARCHITECTURE DESIGN

4.1 CSCI COMPONENTS

The APM CSCI is accessed by a subroutine call which provides, as global data elements, the values specified in Table 1 through Table 4. The source code for the APM CSCI is listed in Appendix A. The name and purpose for each CSC and SU are listed below.

The Advance Propagation Initialization (APMINIT) CSC interfaces with various SUs for the complete initialization of the APM CSCI.

The APMINIT CSC component SUs include the following:

1. **Allocate Arrays APM (ALLARRAY_APM) SU.** Allocates and initializes all dynamically dimensioned arrays associated with APM terrain, refractivity, troposcatter, and general variable arrays.

2. **Allocate Array PE (ALLARRAY_PE) SU.** Allocates and initializes all dynamically dimensioned arrays associated with PE calculations.

3. **Allocate Array RO (ALLARRAY_RO) SU.** Allocates and initializes all dynamically dimensioned arrays associated with RO calculations.

4. **Allocate Array XO (ALLARRAY_XORUF) SU.** Allocates and initializes all dynamically dimensioned arrays associated with XO and rough surface calculations.

5. **Alpha Impedance Initialization (ALN_INIT) SU.** Initializes variables used in the Discrete Mixed Fourier Transform (DMFT) algorithm for finite conductivity and/or rough surface calculations.

6. **Antenna Pattern (ANTPAT) SU.** Calculates a normalized antenna gain (antenna pattern factor) for a specified antenna elevation angle.

7. **APM Status (APMSTATUS) SU.** Declared as an external subroutine within the main driver program. Used only for accessing status of grazing angle routine.

8. **Dielectric Initialization (DIEINIT) SU.** Determines the conductivity and relative permittivity as a function of frequency (MHz) based on general ground composition types.

9. **FFT Parameters (FFTPAR) SU.** Determines the required transform size based on the maximum PE propagation angle and the maximum height needed.

10. **Fill Height Arrays (FILLHT) SU**. Calculates the effective earth radius for an initial launch angle of 5° and fills an array with height values at each output range of the limiting sub-model, depending on which mode is used.

11. **Gaseous Absorption (GASABS) SU.** Computes the specific attenuation based on air temperature and absolute humidity.

12. **Get Effective Earth Radius Factor (GET_K) SU.** Computes the effective earth radius factor and the effective earth radius.

13. **Get Alpha Impedance (GETALN) SU.** Computes the impedance term in the Leontovich boundary condition and the complex index of refraction for finite conductivity and vertical polarization calculations.

14. **Get Angles (GETANGLES) SU.** Computes grazing angles for use in subsequent rough surface calculations, and if necessary, also the propagation angles for output via APMSTEP.

15. **Get Maximum Angle (GETTHMAX) SU.** Performs an iterative ray trace to determine the minimum angle required (based on the reflected ray) in obtaining a PE solution.

16. **Grazing Angle Interpolation (GRAZE_INT) SU**. Interpolates grazing angles at each PE range step based on angles computed from ray trace (takes precedence) and those computed from spectral estimation.

17. **Height Check (HTCHECK) SU**. Checks if the current traced ray height is below the current ground height.

18. **Interpolate Profile (INTPROF) SU.** Performs a linear interpolation vertically with height on the refractivity profile.

19. **PE Initialization (PEINIT) SU.** Initializes all variables used in the PE model for subsequent calls to the PESTEP SU

20. **Poly 4 (FN_POLY4) Function.** Evaluates a fourth degree polynomial.

21. **Poly 5 (FN_POLY5) Function.** Evaluates a fifth degree polynomial.

22. **Profile Reference (PROFREF) SU.** Adjusts the current refractivity profile so that it is relative to a reference height.

23. **Refractivity Initialization (REFINIT) SU.** Checks for valid environmental profile inputs and initializes refractivity arrays.

24. **Remove Duplicate Refractivity Levels (REMDUP) SU.** Removes any duplicate refractivity levels in the currently interpolated profile.

25. **RG Trace (RGTRACE) SU.** Performs ray trace over terrain of many rays launched within an angle of ±1.5°, storing grazing angles from these rays.

26. **Terrain Initialization (TERINIT) SU.** Examines and initializes terrain arrays for subsequent use in PE calculations.

27. **Trace to Output Range (TRACE_ROUT) SU.** Traces a single ray, whose launch angle is specified by the calling routine, to each output range.

28. **Trace to next Step (TRACE_STEP) SU.** This routine performs one ray trace step. When passed a starting angle, range, and height for a single ray, it will trace to the first boundary that occurs (refractivity level or surface). It then passes back the ending angle, range and height, and a flag indicating if the ray has hit the surface.

29. **Troposcatter Initialization (TROPOINIT) SU.** Initializes all variables and arrays needed for subsequent troposcatter calculations.

30. **Starter Field Initialization (XYINIT) SU.** Calculates the complex PE solution at range zero.

The Advanced Propagation Model Step (APMSTEP) CSC advances the entire APM CSCI algorithm one output range step, referencing various SUs to calculate the propagation loss at the current output range. The APMSTEP CSC component SUs include the following:

1. **Calculate Propagation Loss (CALCLOS) SU.** Determines propagation loss from the complex PE field at each output height point at the current output range.

2. **Current Wind (FN_CURWIND) Function.** Performs a linear interpolation in range to get the current wind speed at the specified range.

3. **Dielectric Constant (FN_DIECON) Function.** Extracts the stored complex dielectric constant at a particular range.

4. **DOSHIFT SU.** Shifts the field by the number of bins, or PE mesh heights corresponding to the local ground height.

5. **Discrete Sine/Cosine Fast-Fourier Transform (DRST) SU.** Performs a sine or cosine transform, depending on the value of an integer flag provided by the calling SU, on both the real and imaginary components of the PE field, which are passed separately.

6. **Flat Earth Direct Ray (FEDR) SU.** Determines the propagation loss based on FE calculations for the direct ray only, for all output heights specified at each output range.

7. **Flat Earth Model (FEM) SU.** Computes propagation loss at a specified range based on FE approximations.

8. **Fast-Fourier Transform (FFT) SU.** Separates the real and imaginary components of the complex PE field into two real arrays and then references the DRST SU.

9. **Free Space Range Step (FRSTP) SU.** Propagates the complex PE solution field in free space by one range step.

10. **FZLIM SU.** Determines the propagation factor (in dB) and the outgoing propagation angle at the top of the PE calculation region.

11. **Get Propagation Factor (FN_GETPFAC) Function.** Determines the propagation factor at the specified height in decibels.

12. **Get Reflection Coefficient (GETREFCOEF) SU**. Calculates the complex surface reflection coefficient, along with the Miller–Brown rough surface reduction factor.

13. **Get Troposcatter Loss (FN_GET_TLOSS) Function**. Determines the loss due to troposcatter and computes the appropriate loss from troposcatter and diffraction for a specific transmitter and receiver point over land and water.

14. **Linear Interpolation (FN_PLINT) Function.** Performs linear interpolation on two input parameters passed to the function.

15. **Mixed Fourier Transform (MIXEDFT) SU.** Propagates the PE field in free space one PE range step, applying the Leontovich boundary condition, using the mixed Fourier transform as outlined by Kuttler and Dockery (1991).

16. **Parabolic Equation Step (PESTEP) SU.** Determines the next output range and begins an iterative loop to advance the PE solution such that for the current PE range, a PE solution is calculated from the solution at the previous PE range. This procedure is to be repeated until the output range is reached.

17. **Ray Trace (RAYTRACE) SU.** Traces a ray from a starting height and range with a specified starting elevation angle to a termination range.

18. **Refractivity Interpolation (REFINTER) SU.** Interpolates horizontally and vertically on the modified refractivity profiles.

19. **Ray Optics Calculation (ROCALC SU).** Computes the RO components that will be needed in the calculation of propagation loss at a specified range and height within the RO region.

20. **Ray Optics Loss (ROLOSS) SU.** Calculates the propagation loss and propagation factor values at a specified range and height based upon the components of magnitude for a direct-path and surface-reflected ray and the total phase lag angle between the two rays as determined by the ROCALC SU.

21. **Save Profile (SAVEPRO) SU.** Stores the refractivity profiles at each PE range step from the top of the PE region to the maximum user-specified height.

22. **Spectral Estimation (SPECEST) SU.** Determines, via spectral estimation, the outward propagation angle at the top of the PE calculation region.

23. **Surface Impedance (SURFIMP) SU.** Computes the normalized average surface impedance for surface wave propagation by vertically polarized waves along the sea surface for frequencies less than 50 MHz.

24. **Troposcatter (TROPOSCAT) SU**. Determines the loss due to troposcatter and computes the appropriate loss from troposcatter and diffraction beyond the radio horizon for an array of receiver heights.

The XOINIT CSC initializes the range, height, and angle arrays in preparation for the XOSTEP CSC. It also accesses the surface clutter computation SUs and returns the surface clutter, if specified by the user. The XOINIT CSC component SUs include the following:

1. **Advanced Propagation Model Clean (APMCLEAN) SU.** Deallocates all dynamically dimensioned arrays used in one complete run of APM calculations.

2. **Clutter-to-Noise (CLUTTER) SU.** Calculates returned clutter-to-noise ratio at each output range.

3. **Diffraction Loss (FN_DLOSS) Function.** Computes loss in the diffraction region based on the CCIR model.

4. **Get Theta (GETTHETA) SU.** Calculates the optical phase-lag difference angle from the reflection range found in the R1ITER SU.

5. **GIT Initialization (GIT_INIT) SU.** Initializes all variables used in the calculation of the reflectivity based on a modified version of the GIT model.

6. **GofZ (GOFZ) Function.** Calculates the diffraction region height-gain in decibels from the CCIR diffraction region model.

7. **Mean Filter (MEANFILT) SU.** Performs an n-point average smoothing on any array passed to it.

8. **Optical Region Limit (OPLIMIT) SU.** Calculates the maximum range in the optical interference region and the corresponding loss at that range.

9. **Optical Difference (OPTICF) SU.** Calculates the optical path-length difference angle by solving a cubic equation for the reflection point range.

10. **R1 Iteration (R1ITER) SU.** Finds the range of the reflection point corresponding to a particular launch angle.

11. **Standard Propagation Model Initialization (SPM_INIT) SU.** Initializes much of the variables used throughout the SPM SU.

12. **Standard Propagation Model (SPM) SU.** Computes the propagation factor for a standard atmosphere only, with the assumption of omni-directional antenna patterns.

The XOSTEP CSC advances the APM CSCI algorithm one output range step from the top of the PE calculation region to the maximum output height specified, referencing various SUs to calculate the propagation loss at the current output range. The XOSTEP CSC component SUs include the following:

1. **Extended Optics (EXTO) SU.** Calculates propagation loss and propagation factor, based on extended optics techniques, at the current output range.

The Return Grazing Angles (RET_GRAZE) CSC interpolates grazing angles to every output range step, and if necessary, will interpolate the propagation angles in height at every output range.

4.2 CONCEPT OF EXECUTION

The program flow of the APM CSCI is illustrated in Figure 2. Note that the APM CSCI is shown within the context of a calling CSCI application such as one that generates a coverage or loss diagram. The efficient implementation of the APM CSCI will have far reaching consequences on the design of an application CSCI beyond those mentioned in Section 7.1. For example, Figure 2 shows checking for the existence of a previously created APM output file prior to the access of the APM CSCI. The application CSCI must consider if the atmospheric or terrain environment has changed since the APM output file was created or if any new height or range requirement is accommodated within the existing APM CSCI output file. Because these and many more considerations are beyond the scope of this document, an application CSCI designer should work closely with the APM CSCI development agency in the implementation of the APM CSCI.

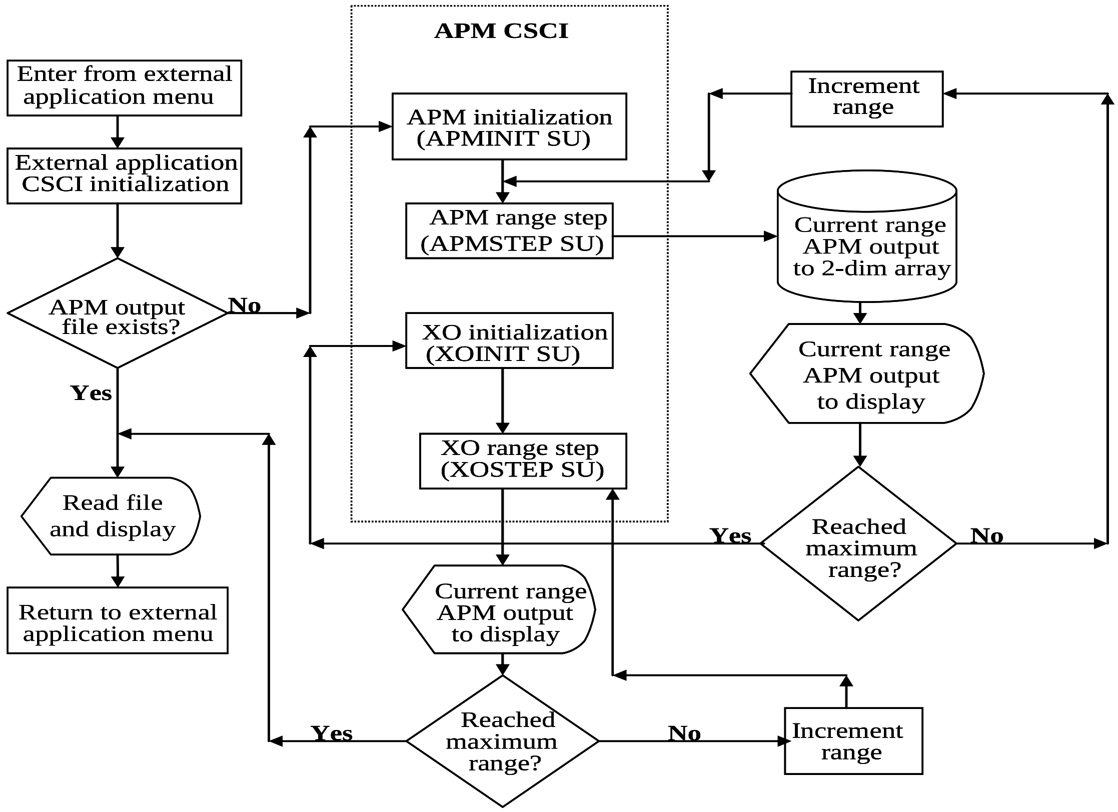

Figure 2. APM CSCI program flow.

4.3 INTERFACE DESIGN

4.3.1 Interface Identification and Diagrams

The APM CSCI interface design consists of one FORTRAN MODULE file for the external and internal data interface, FORTRAN CALL statements for output data and internal interfacing, and several FORTRAN COMMON blocks for the internal interface. The MODULE file is called APM_MOD. This MODULE's statements provide several constants, COMMON blocks, and the dynamically allocated array names. The COMMON block names are (1) APM_VAR, (2) ERRORFLAG, (3) INPUTVAR, (4) REFRACTIVITY, (5) SYSTEMVAR, and (6) TERRAIN.

4.3.2 External Interface

The APM CSCI is accessed, through the APMINIT CSC, by a subroutine call from the external CSCI, which should provide, as global data elements, the values specified in Table 1 through Table 4.

The APM CSCI external data elements, i.e. those data which must be provided by the calling CSCI in the MODULE file prior to the APM CSCI execution can be divided into four classifications. The first classification is external data related to the atmospheric environment (Table 1), the second is data related to the EM system (Table 2), the third is

data related to the implementation of the APM CSCI by the external CSCI (Table 3), and the fourth is data related to the terrain information (Table 4). Each table lists the type, units, and bounds of each data element. Table 5 specifies the output data of the APM CSCI model passed back to the calling CSCI via the FORTRAN CALL statements.

Table 1. APM CSCI environmental data element requirements.

Name	Description	Type	Units	Bounds
refmsl	Modified refractivity profile (dynamically allocated) array referenced to mean sea level	real	M	≥ 0.0[a]
hmsl	Profile height (dynamically allocated) array	real	meters	See note b
n_{prof}	Number of refractivity profiles	integer	N/A	≥ 1
lvlp	Number of profile levels	integer	N/A	≥ 2
rngprof	Dynamically allocated array of ranges to each profile	real	meters	≥ 0.0
abs_{hum}	Surface absolute humidity	real	g/m^3	0 to 50[c]
t_{air}	Surface air temperature	real	°C	-20 to 40[c]
γ_a	Surface specific attenuation	real	dB/km	≥ 0.0
i_{extra}	Extrapolation flag for refractivity profiles entered in combination with terrain below mean sea level	integer	N/A	0 or 1
n_w	Number of wind speeds and corresponding ranges	integer	N/A	≥ 0.0
rngwind	Dynamically allocated array of ranges specified for each wind speed in *wind()*.	real	meters	≥ 0.0
wind	Dynamically allocated array of wind speeds.	real	meters/ second	0.0 to 20.0[d]
$wind_{dir}$	Angle between antenna boresight and upwind direction	real	degrees	0.0 to 360.0

[a]Couplets of height and modified refractivity associated with that height are referred to in this document as a refractivity profile.

[b]All heights in the refractivity profile must be steadily increasing.

[c]The CCIR gaseous absorption model implemented within APM provides a ±15% accuracy for absolute humidity and surface air temperature within these bounds. While values beyond these limits are allowed within APM, Note that this may result in less accurate attenuation rates calculated.

[d]The maximum wind speed will vary depending on frequency. For frequencies less than 10 GHz, the maximum that can be specified is 20 m/s. Above 10 GHz, the maximum wind speed that can be specified will decrease to an absolute maximum of 15 m/s at 20 GHz and above.

Table 2. APM CSCI external EM system data element requirements.

Name	Description	Type	Units	Bounds
μ_{bw}	Antenna vertical beam width	real	degree	0.5 to 45
μ_o	Antenna elevation angle	real	degree	-10.0 to 10.0
C_{lut}	Logical flag used to indicate if surface clutter calculations are desired.	logical	N/A	'.true.' or '.false.'
f_{MHz}	EM system frequency	real	MHz	2.0 to 20,000.0[a]
i_{pat}	Antenna pattern 1 = Omnidirectional 2 = Gaussian 3 = Sine (X)/X 4 = Cosecant-squared 5 = Generic height-finder 6 = User-defined height-finder 7 = User-defined antenna pattern 8 = Quarter-wave dipole	integer	N/A	1 to 8
i_{pol}	Antenna polarization 0 = Horizontal 1 = Vertical	integer	N/A	0 to 1
G	Gain of transmit/receive antennas	real	dBi	$\geq$ 0.0
ant_{ht}	Antenna height above local ground at range 0.0 m	real	meters	$\geq$ 1.5[b]
$hfang$	Dynamically allocated user-defined height-finder power reduction angle array (i_{pat}=6) or antenna pattern angles (i_{pat}=7)	real	degree	0.0 to 90.0 for i_{pat}=6 -90.0 to 90.0 for i_{pat}=7
$hffac$	Dynamically allocated user-defined power reduction factor array (i_{pat}=6) or antenna pattern factors (i_{pat}=7)	real	N/A	0.0 to 1.0
L_{sys}	Miscellaneous system losses	real	dB	$\geq$ 0.0
θ_{hbw}	Antenna horizontal beam width	real	degrees	0.5 to 45
n_{facs}	Number of power reduction angles/factors for user-defined height finder antenna pattern	integer	N/A	1 to 10
N_f	Noise figure	real	dB	$\geq$ 0.0
P_t	Transmitter peak power	real	kW	$\geq$ 0.1
τ	Pulse length/width	real	μsec	$\geq$ 0.1

[a]The frequency can be specified greater than 20 GHz; however, the PE_{flag} must be set to '.true.' and care must be taken in specifying th_{max} and r_{mult}.

[b]The minimum antenna height will vary, depending on the frequency and beamwidth according to the formula:

$$ant_{ht} \geq maximum\ of\left(1.5, 0.6\frac{c_o}{f_{MHz}\ \mu_{bw}}\right)$$

where c_o is the speed of light x 10^{-6} m/s (299.79245).

Table 3. APM CSCI external implementation constants.

Name	Description	Type	Units	Bounds
h_{max}	Maximum height output for a particular application of APM	real	meters	≥ 100.0[a]
h_{min}	Minimum height output for a particular application of APM	real	meters	≥ 0.0[a]
lang	Propagation angle and factor output flag ‘.true.’= Output propagation angle and propagation factor for direct and reflected ray (where applicable). ‘.false.’ = Do not output propagation angles and factors	logical	N/A	‘.true.’ or ‘.false.’[b]
lerr6	Logical flag to allow for error -6 to be bypassed	logical	N/A	‘.true.’ or ‘.false.’[c]
lerr12	Logical flag to allow for error -12 to be bypassed	logical	N/A	‘.true.’ or ‘.false.’[c]
n_{rout}	Number of range output points for a particular application of APM	integer	N/A	≥ 1
n_{zout}	Number of height output points for a particular application of APM	integer	N/A	≥ 1
n_{zout_rtg}	Number of height output points for receiver heights relative to the local ground elevation.	integer	N/A	≥ 0
PE_{flag}	Flag to indicate use of PE algorithm only: ‘.true.’ = only use PE sub-model ‘.false.’ = use automatic hybrid model	logical	N/A	‘.true.’ or ‘.false.’[c]
r_{max}	Maximum range output for a particular application of APM	real	meters	≥ 5000.0[c]
r_{mult}	PE-range step multiplier	real	N/A	> 0.0[c]
th_{max}	Visible portion of PE maximum calculation angle	real	degrees	> 0.0[c]
T_{ropo}	Logical flag to include troposcatter calculations.	integer	N/A	‘.true.’ or ‘.false.’
zout_rtg	Dynamically allocated array of receiver heights specified relative to the local ground height.	real	meters	≥ 0.0

[a]Refer to section 7.2 for a complete description.

[b]This flag should not be enabled when any portion of the propagation path is over land.

[c]Refer to section 4.3.4 for a complete description.

Table 4. APM CSCI external terrain data element requirements.

Name	Description	Type	Units	Bounds
terx	Dynamically allocated terrain profile range array	real	meters	≥ 0.0[a]
tery	Dynamically allocated terrain profile height array	real	meters	≥ 0.0[a]
γc	Dynamically allocated array of constants describing the backscattering effectiveness of the surface	real	dB	$-100.0 \le \gamma c \le 100.0$
γrng	Dynamically allocated array of ranges corresponding to the values in γc	real	meters	≥ 0.0
i_{gc}	Number of γc values for a particular application of APM	integer	N/A	≥ 0
i_{tp}	Number of terrain profile points for a particular application of APM	integer	N/A	≥ 2
i_{gr}	Number of ground types for a particular application of APM	integer	N/A	≥ 0[a]
igrnd	Array of ground composition types for a particular application of APM 0 = Sea water 1 = Fresh water 2 = Wet ground 3 = Medium dry ground 4 = Very dry ground 5 = Ice at -1° C 6 = Ice at -10° C 7 = User-defined	integer	N/0A	0 ≤ *igrnd* ≤ 7[a]
rgrnd	Dynamically allocated array of ranges for which ground types are applied for a particular application of APM	real	meters	≥ 0.0[a]
dielec	Dynamically allocated two-dimensional array of relative permittivity (ε_r) and conductivity (σ) for a particular application of APM	real	ε_r - N/A σ- Siemens/ meter	>0[a]

[a]refer to section 7.3 for a complete description

Table 5. APM CSCI output data element requirements.

Name	Description	Type	Units	Source
CNR	Clutter-to-Noise ratio array	real	dB	XOINIT CSC
Ψ_{rout}	Array of grazing angles at each output range r_{out}	real	radians	RET_GRAZE SU
i_{error}	Integer value that is returned if an error occurs in called routine	integer	N/A	APMINIT CSC RET_GRAZE SU XOINIT CSC
i_{xostp}	Index of output range step at which XO model is to be applied	integer	N/A	APMINIT CSC
j_{end}	Output height index at which valid propagation loss values end	integer	N/A	APMSTEP CSC
j_{start}	Output height index at which valid propagation loss values begin	integer	N/A	APMSTEP CSC
j_{xend}	Output height index at which valid XO propagation loss values end	integer	N/A	XOSTEP CSC
j_{xstart}	Output height index at which valid XO propagation loss values begin	integer	N/A	XOINIT CSC
l_{graze}	Logical flag indicating if grazing angles were computed for a particular application of APM	logical	N/A	APMINIT CSC
mpfl	Propagation loss and factor array	integer	cB	APMSTEP CSC XOSTEP CSC
mpfl_rtg	Propagation loss and factor at receiver heights specified in the *zout_rtg* array	integer	cB	APMSTEP CSC
propaf	Two-dimensional array, containing the propagation angles and factors for the direct and reflected rays (where applicable) for all output height/range points	real	radians,dB	APMSTEP CSC XOSTEP CSC
r_{out}	Current output range	real	meters	APMSTEP CSC XOSTEP CSC

4.3.3 Internal Interface

Section 4.2 shows the relationship between the APM CSCI and its five main CSCs: APMINIT, AMPSTEP, RET_GRAZE, XOINIT, and XOSTEP. This relationship is illustrated in Figure 2. The internal interface between these five CSCs and the APM CSCI is left to the design. However, the internal structure of the APM CSCI and its CSCs and SUs is shown in Table 6. The left two columns show the calling subroutines, and the right two columns the subroutines called. Columns 2 and 4 in Table 6 give the section number in Section 5 where more details about the various CSCs and SUs of the APM CSCI can be found.

Table 6. APM internal interface design.

Software Design Description		Software Design Description	
Software Design Description Name	SDD Paragraph Number	Software Design Description Name	SDD Paragraph Number
CSCI Detailed Design	5	Advance Propagation Initialization (APMINIT) CSC	5.1
Advance Propagation Initialization (APMINIT) CSC	5.1	Allocate Arrays APM (ALLARRAY_APM) SU	5.1.1
Advance Propagation Initialization (APMINIT) CSC	5.1	Allocate Array RO (ALLARRAY_RO) SU	5.1.3
Advance Propagation Initialization (APMINIT) CSC	5.1	Allocate Array XORUF (XORUF) SU	5.1.4
Advance Propagation Initialization (APMINIT) CSC	5.1	Alpha Impedance Initialization (ALN_INIT) SU	5.1.5
Alpha Impedance Initialization (ALN_INIT) SU	5.1.5	Get Alpha Impedance (GETALN) SU	5.1.13
Get Alpha Impedance(GETALN) SU	5.1.13	Current Wind (FN_CURWIND) Function	5.2.2
Get Alpha Impedance(GETALN) SU	5.1.13	Get Reflection Coefficient (GETREFCOEF) SU	5.2.12
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Current Wind (FN_CURWIND) Function	5.2.2
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Dielectric Constant (FN_DIECON) Function	5.2.3
Get Alpha Impedance(GETALN) SU	5.1.13	Surface Impedance (SURFIMP) SU	5.2.23
Surface Impedance (SURFIMP) SU	5.2.23	Poly 4 (FN_POLY4) Function	5.1.20
Surface Impedance (SURFIMP) SU	5.2.23	Poly 5 (FN_POLY5) Function	5.1.21
Advance Propagation Initialization (APMINIT) CSC	5.1	Dielectric Initialization (DIEINIT) SU	5.1.8
Advance Propagation Initialization (APMINIT) CSC	5.1	FFT Parameters (FFTPAR) SU	5.1.9
Advance Propagation Initialization (APMINIT) CSC	5.1	Fill Height Arrays (FILLHT) SU	5.1.10
Fill Height Arrays (FILLHT) SU	5.1.10	Trace to Output Range (TRACE_ROUT) SU	5.1.27

Table 6. APM internal interface design. (continued)

Software Design Description		Software Design Description	
Software Design Description Name	SDD Paragraph Number	Software Design Description Name	SDD Paragraph Number
Fill Height Arrays (FILLHT) SU	5.1.10	Trace to Next Step (TRACE_STEP) SU	5.1.28
Trace to Next Step (TRACE_STEP) SU	5.1.28	Height Check (HTCHECK) SU	5.1.17
Advance Propagation Initialization (APMINIT) CSC	5.1	Gaseous Absorption (GASABS) SU	5.1.11
Advance Propagation Initialization (APMINIT) CSC	5.1	Get Effective Earth Radius Factor (GET_K) SU	5.1.12
Advance Propagation Initialization (APMINIT) CSC	5.1	Get Angles (GETANGLES) SU	5.1.14
Get Angles (GETANGLES) SU	5.1.14	APM Status (APMSTATUS) SU	5.1.7
Get Angles (GETANGLES) SU	5.1.14	DOSHIFT SU	5.2.2
Get Angles (GETANGLES) SU	5.1.14	Free Space Range Step (FRSTP) SU	5.2.9
Free Space Range Step (FRSTP) SU	5.2.9	Fast Fourier Transform (FFT) SU	5.2.8
Fast Fourier Transform (FFT) SU	5.2.8	Discrete Sine/Cosine Transform (DRST) SU	5.2.5
Get Angles (GETANGLES) SU	5.1.14	Refractivity Interpolation (REFINTER) SU	5.2.18
Refractivity Interpolation (REFINTER) SU	5.2.18	Interpolate Profile (INTPROF) SU	5.1.18
Interpolate Profile (INTPROF) SU	5.1.18	Linear Interpolation (FN_PLINT) Function	5.2.14
Refractivity Interpolation (REFINTER) SU	5.2.18	Profile Reference (PROFREF) SU	5.1.22
Refractivity Interpolation (REFINTER) SU	5.2.18	Remove Duplicate Refractivity Levels (REMDUP) SU	5.1.24
Get Angles (GETANGLES) SU	5.1.14	RG Trace (RGTRACE) SU	5.1.25
RG Trace (RGTRACE) SU	5.1.25	Trace to Next Step (TRACE_STEP) SU	5.1.28

Table 6. APM internal interface design. (continued)

Software Design Description		**Software Design Description**	
Software Design Description Name	SDD Paragraph Number	Software Design Description Name	SDD Paragraph Number
Trace to Next Step (TRACE_STEP) SU	5.1.28	Height Check (HTCHECK) SU	5.1.17
Get Angles (GETANGLES) SU	5.1.14	Spectral Estimation (SPECEST) SU	5.2.22
Spectral Estimation (SPECEST) SU	5.2.22	Discrete Sine/Cosine Transform (DRST) SU	5.2.5
Get Angles (GETANGLES) SU	5.1.14	Trace to Output Range (TRACE_ROUT) SU	5.1.27
Advance Propagation Initialization (APMINIT) CSC	5.1	Get Maximum Angle (GETTHMAX) SU	5.1.15
Get Maximum Angle (GETTHMAX) SU	5.1.15	FFT Parameters (FFTPAR) SU	5.1.9
Get Maximum Angle (GETTHMAX) SU	5.1.15	Trace to Output Range (TRACE_ROUT) SU	5.1.27
Advance Propagation Initialization (APMinit) CSC	5.1	Grazing Angle Interpolation (GRAZE_INT) SU	5.1.16
Grazing Angle Interpolation (GRAZE_INT) SU	5.1.16	Linear Interpolation (FN_PLINT) Function	5.2.14
Advance Propagation Initialization (APMinit) CSC	5.1	PE Initialization (PEINIT) SU	5.1.19
PE Initialization (PEINIT) SU	5.1.19	Allocate Array PE (ALLARRAY_PE) SU	5.1.2
PE Initialization (PEINIT) SU	5.1.19	Interpolate Profile (INTPROF) SU	5.1.18
PE Initialization (PEINIT) SU	5.1.19	Starter Field Initialization (XYINIT) SU	5.1.30
Starter Field Initialization (XYINIT) SU	5.1.30	Antenna Pattern (ANTPAT) SU	5.1.6
Starter Field Initialization (XYINIT) SU	5.1.30	Discrete Sine/Cosine Transform (DRST) SU	5.2.5
Advance Propagation Initialization (APMINIT) CSC	5.1	Profile Reference (PROFREF) SU	5.1.22
Advance Propagation Initialization (APMINIT) CSC	5.1	Refractivity Initialization (REFINIT) SU	5.1.23

Table 6. APM internal interface design. (continued)

Software Design Description		Software Design Description	
Software Design Description Name	SDD Paragraph Number	Software Design Description Name	SDD Paragraph Number
Refractivity Initialization (REFINIT) SU	5.1.23	Profile Reference (PROFREF) SU	5.1.22
Refractivity Initialization (REFINIT) SU	5.1.23	Remove Duplicate Refractivity Levels (RemDup) SU	5.1.24
Advance Propagation Initialization (APMINIT) CSC	5.1	Remove Duplicate Refractivity Levels (RemDup) SU	5.1.24
Advance Propagation Initialization (APMINIT) CSC	5.1	Terrain Initialization (TERINIT) SU	5.1.26
Advance Propagation Initialization (APMINIT) CSC	5.1	Troposcatter Initialization (TROPOINIT) SU	5.1.28
Troposcatter Initialization (TROPOINIT) SU	5.1.28	Antenna Pattern(Antpat) SU	5.1.6
Troposcatter Initialization (TROPOINIT) SU	5.1.28	Get Effective Earth Radius Factor (GET_K) SU	5.1.12
CSCI Detailed Design	5	Advance Propagation Model Step (APMSTEP) CSC	5.2
Advance Propagation Model Step (APMSTEP) CSC	5.2	Flat Earth Direct Ray (FEDR) SU	5.2.6
Flat Earth Direct Ray (FEDR) SU	5.2.6	Antenna Pattern(Antpat) SU	5.1.6
Advance Propagation Model Step (APMSTEP) CSC	5.2	Flat Earth Model (FEM) SU	5.2.7
Flat Earth Model (FEM) SU	5.2.7	Antenna Pattern (Antpat) SU	5.1.6
Flat Earth Model (FEM) SU	5.2.7	Get Reflection Coefficient (GETREFCOEF) SU	5.2.12
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Current Wind (FN_CURWIND) Function	5.2.2
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Dielectric Constant (FN_DIECON) Function	5.2.3
Advance Propagation Model Step (APMSTEP) CSC	5.2	Parabolic Equation Step (PESTEP) SU	5.2.16
Parabolic Equation Step (PESTEP) SU	5.2.16	Calculate Propagation Loss (CALCLOS) SU	5.2.1

Table 6. APM internal interface design. (continued)

Software Design Description		Software Design Description	
Software Design Description Name	SDD Paragraph Number	Software Design Description Name	SDD Paragraph Number
Calculate Propagation Loss (CALCLOS) SU	5.2.1	Get Propagation Factor (FN_GETPFAC) Function	5.2.11
Calculate Propagation Loss (CALCLOS) SU	5.2.1	Linear Interpolation (FN_PLINT) Function	5.2.14
Calculate Propagation Loss (CALCLOS) SU	5.2.1	Troposcatter (TROPOSCAT) SU	5.2.24
Troposcatter (TROPOSCAT) SU	5.2.24	Get Troposcatter Loss (FN_GET_TLOSS) Function	5.2.13
Get Troposcatter Loss (FN_GET_TLOSS) Function	5.2.13	Antenna Pattern (ANTPAT) SU	5.1.6
Parabolic Equation Step (PESTEP) SU	5.2.16	DOSHIFT SU	5.2.4
Parabolic Equation Step (PESTEP) SU	5.2.16	Free Space Range Step (FRSTP) SU	5.2.9
Free Space Range Step (FRSTP) SU	5.2.9	Fast-Fourier Transform (FFT) SU	5.2.8
Fast-Fourier Transform (FFT) SU	5.2.8	Discrete Sine/Cosine Transform (DRST) SU	5.2.5
Parabolic Equation Step (PESTEP) SU	5.2.16	FZLIM SU	5.2.10
FZLIM SU	5.2.10	Get Propagation Factor (FN_GETPFAC) Function	5.2.11
FZLIM SU	5.2.10	Save Profile (SAVEPRO) SU	5.2.21
FZLIM SU	5.2.10	Spectral Estimation (SPECEST) SU	5.2.22
Spectral Estimation (SPECEST) SU	5.2.22	Discrete Sine/Cosine Transform (DRST) SU	5.2.5
Parabolic Equation Step (PESTEP) SU	5.2.16	Get Alpha Impedance (GETALN) SU	5.1.13
Get Alpha Impedance (GETALN) SU	5.1.13	Current Wind (FN_CURWIND) Function	5.2.2
Get Alpha Impedance (GETALN) SU	5.1.13	Get Reflection Coefficient (GETREFCOEF) SU	5.2.12
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Current Wind (FN_CURWIND) Function	5.2.2

Table 6. APM internal interface design. (continued)

Software Design Description		Software Design Description	
Software Design Description Name	SDD Paragraph Number	Software Design Description Name	SDD Paragraph Number
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Dielectric Constant (FN_DIECON) Function	5.2.3
Get Alpha Impedance(GETALN) SU	5.1.13	Surface Impedance (SURFIMP) SU	5.2.23
Surface Impedance (SURFIMP) SU	5.2.23	Poly 4 (FN_POLY4) Function	5.1.20
Surface Impedance (SURFIMP) SU	5.2.23	Poly 5 (FN_POLY5) Function	5.1.21
Parabolic Equation Step (PESTEP) SU	5.2.16	Mixed Fourier Transform (MIXEDFT) SU	5.2.15
Mixed Fourier Transform (MIXEDFT) SU	5.2.15	Free Space Range Step (FRSTP) SU	5.2.9
Free Space Range Step (FRSTP) SU	5.2.9	Fast-Fourier Transform (FFT) SU	5.2.8
Fast-Fourier Transform (FFT) SU	5.2.8	Discrete Sine/Cosine Transform (DRST) SU	5.2.5
Parabolic Equation Step (PESTEP) SU	5.2.16	Refractivity Interpolation (REFINTER) SU	5.2.18
Refractivity Interpolation (REFINTER) SU	5.2.18	Interpolate Profile (INTPROF) SU	5.1.18
Interpolate Profile (INTPROF) SU	5.1.18	Linear Interpolation (FN_PLINT) Function	5.2.14
Refractivity Interpolation (REFINTER) SU	5.2.18	Profile Reference (PROFREF) SU	5.1.22
Refractivity Interpolation (REFINTER) SU	5.2.18	Remove Duplicate Refractivity Levels (REMDUP) SU	5.1.24
Advance Propagation Model Step (APMSTEP) CSC	5.2	Ray Optics Loss (ROLOSS) SU	5.2.20
Ray Optics Loss (ROLOSS) SU	5.2.20	Ray Optics Calculation (ROCALC) SU	5.2.19
Ray Optics Calculation (ROCALC) SU	5.2.19	Antenna Pattern (ANTPAT) SU	5.1.6
Ray Optics Calculation (ROCALC) SU	5.2.19	Get Reflection Coefficient (GETREFCOEF) SU	5.2.12

Table 6. APM internal interface design. (continued)

Software Design Description		Software Design Description	
Software Design Description Name	SDD Paragraph Number	Software Design Description Name	SDD Paragraph Number
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Current Wind (FN_CURWIND) Function	5.2.2
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Dielectric Constant (FN_DIECON) Function	5.2.3
Ray Optics Calculation (ROCALC) SU	5.2.19	Ray Trace (RAYTRACE) SU	5.2.17
CSCI Detailed Design	5	Extended Optics Initialization (XOINIT) CSC	5.3
Extended Optics Initialization (XOINIT) CSC	5.3	APM Clean (APMCLEAN) SU	5.3.1
APM Clean (APMCLEAN) SU	5.3.1	Discrete Sine/Cosine (DRST) SU	5.2.5
Extended Optics Initialization (XOINIT) CSC	5.3	Clutter-to-Noise (CLUTTER) SU	5.3.2
Clutter-to-Noise (CLUTTER) SU	5.3.2	GIT Initialization (GIT_INIT) SU	5.3.5
GIT Initialization (GIT_INIT) SU	5.3.5	Current Wind (FN_CURWIND) Function	5.2.2
Clutter-to-Noise (CLUTTER) SU	5.3.2	Standard Propagation Model Initialization (SPM_INIT) SU	5.3.11
Clutter-to-Noise (CLUTTER) SU	5.3.2	Standard Propagation Model (SPM) SU	5.3.12
Standard Propagation Model (SPM) SU	5.3.12	Diffraction Loss (FN_DLOSS) Function	5.3.3
Standard Propagation Model (SPM) SU	5.3.12	GofZ (FN_GOFZ) Function	5.3.6
Standard Propagation Model (SPM) SU	5.3.12	Optical Region Limit (OPLIMIT) SU	5.3.8
Optical Region Limit (OPLIMIT) SU	5.3.8	Get Theta (GETTHETA) SU	5.3.4
Get Theta (GETTHETA) SU	5.3.4	Get Reflection Coefficient (GETREFCOEF) SU	5.2.12
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Current Wind (FN_CURWIND) Function	5.2.2

Table 6. APM internal interface design. (continued)

Software Design Description		Software Design Description	
Software Design Description Name	SDD Paragraph Number	Software Design Description Name	SDD Paragraph Number
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Dielectric Constant (FN_DIECON) Function	5.2.3
Optical Region Limit (OPLIMIT) SU	5.3.8	R1 Iteration (R1ITER) SU	5.3.10
R1 Iteration (R1ITER) SU	5.3.10	Get Theta (GETTHETA) SU	5.3.4
Get Theta (GETTHETA) SU	5.3.4	Get Reflection Coefficient (GETREFCOEF) SU	5.2.12
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Current Wind (FN_CURWIND) Function	5.2.2
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Dielectric Constant (FN_DIECON) Function	5.2.3
Standard Propagation Model (SPM) SU	5.3.12	Optical Difference (OPTICF) SU	5.3.9
Optical Difference (OPTICF) SU	5.3.9	Get Reflection Coefficient (GETREFCOEF) SU	5.2.12
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Current Wind (FN_CURWIND) Function	5.2.2
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Dielectric Constant (FN_DIECON) Function	5.2.3
Extended Optics Initialization (XOINIT) CSC	5.3	Mean Filter (MEANFILT) SU	5.3.7
CSCI Detailed Design	5	Extended Optics Step (XOSTEP) CSC	5.4
Extended Optics Step (XOSTEP) CSC	5.4	APM Clean (APMCLEAN) SU	5.3.1
APM Clean (APMCLEAN) SU	5.3.1	Discrete Sine/Cosine Transform (DRST) SU	5.2.5
Extended Optics Step (XOSTEP) CSC	5.4	Extended Optics (EXTO) SU	5.4.1
Extended Optics (EXTO) SU	5.4.1	Linear Interpolation (FN_PLINT) Function	5.2.14
Extended Optics (EXTO) SU	5.4.1	Troposcatter (TROPOSCAT) SU	5.2.24
Troposcatter (TROPOSCAT) SU	5.2.24	Get Troposcatter Loss (FN_GET_TLOSS) Function	5.2.13

Table 6. APM internal interface design. (continued)

Software Design Description		**Software Design Description**	
Software Design Description Name	SDD Paragraph Number	Software Design Description Name	SDD Paragraph Number
Get Troposcatter Loss (FN_GET_TLOSS) Function	5.2.13	Antenna Pattern (ANTPAT) SU	5.1.6
Extended Optics Step (XOSTEP) CSC	5.4	Flat Earth Model (FEM) SU	5.2.7
Flat Earth Model (FEM) SU	5.2.7	Antenna Pattern (ANTPAT) SU	5.1.6
Flat Earth Model (FEM) SU	5.2.7	Get Reflection Coefficient (GETREFCOEF) SU	5.2.12
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Current Wind (FN_CURWIND) Function	5.2.2
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Dielectric Constant (FN_DIECON) Function	5.2.3
Extended Optics Step (XOSTEP) CSC	5.4	Ray Optics Loss (ROLOSS) SU	5.2.20
Ray Optics Loss (ROLOSS) SU	5.2.20	Ray Optics Calculation (ROCALC) SU	5.2.19
Ray Optics Calculation (ROCALC) SU	5.2.19	Antenna Pattern (ANTPAT) SU	5.1.6
Ray Optics Calculation (ROCALC) SU	5.2.19	Get Reflection Coefficient (GETREFCOEF) SU	5.2.12
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Current Wind (FN_CURWIND) Function	5.2.2
Get Reflection Coefficient (GETREFCOEF) SU	5.2.12	Dielectric Constant (FN_DIECON) Function	5.2.3
Ray Optics Calculation (ROCALC) SU	5.2.19	Ray Trace (RAYTRACE) SU	5.2.17
CSCI Detailed Design	5	Return Grazing Angle (RET_GRAZE) CSC	5.5

4.3.4 Internal Data

The APM CSCI takes full advantage of Fortran 95 features, utilizing allocatable arrays for all internal and input arrays. The external CSCI designer must correctly allocate and initialize all arrays necessary for input to the APM CSCI.

Due to the computational intensity of the APM CSCI, it may not be necessary or desirable to use the extreme capability of the APM CSCI for all applications. The variables n_{rout} and n_{zout} refer to the desired number of range and height output points for any one particular application, and will be specified when the APMINIT CSC is called.

One of the parameters returned to the external application from the APMINIT CSC is i_{error}, which allows for greater flexibility in how input data are handled in the external application. Table 7 lists all possible errors that can be returned.

The logical variables *lerr6* and *lerr12*, when set to '.false.', allow the external application to bypass their associated errors, as these are not critical to the operation of the APM CSCI.

Table 7. APMINIT SU returned error definitions.

i_{error}	**Definition**
-5	Frequency input must be greater than or equal to 2 MHz.
-6	Last range in terrain profile is less than r_{max}. Will only return this error if *lerr6* set to '.true.'.
-7	Specified cut-back angles (for user-defined height finder antenna pattern) are not increasing.
-8	h_{max} is less than maximum height of terrain profile.
-9	Antenna height with respect to mean sea level is greater than maximum height h_{max}.
-10	Beamwidth is less than or equal to zero for directional antenna pattern.
-11	Number of antenna pattern or power reduction factors and angles is less than or equal to 1. For i_{pat} = 6, n_{facs} must be at least 1; for i_{pat} = 7, n_{facs} must be at least 2.
-12	Range of last environment profile given (for range-dependent case) is less than r_{max}. Will only return this error if *lerr12* set to '.true.'.
-13	Height of first level in any user-specified refractivity profile is greater than 0. First height must be at mean sea level (0.0) or < 0.0 if below mean sea level.
-14	Last gradient in any environment profile is negative.
-17	Range points of terrain profile are not increasing.
-18	First range value in terrain profile is not 0.
-21	Clutter calculations are specified but no transmitter power has been provided.
-22	Clutter calculations are specified but no pulse length has been provided.
-23	Clutter calculations are specified, but no horizontal beamwidth has been provided.
-24	Clutter calculations are desired over terrain or for frequencies less than 1 GHz, but no γc values have been specified.
-25	Specified only the PE model to be used but did not specify maximum propagation angle th_{max}.
-26	Clutter calculations are specified with the propagation path partly or entirely, over water but did not specify a wind speed.
-41	Transmitter height is less than 1.5 meters.
-42	Minimum height input by user, h_{min}, is greater than maximum height, h_{max}.

Table 7. APMINIT SU returned error definitions (continued).

i_{error}	Definition
-43	Transform size is greater than 2^{30}.
-44	Combination of frequency and antenna beamwidth results in antenna physically below the surface. Increase frequency or beamwidth for valid combination.
-45	Wind speed specified is greater than the maximum allowed for the specified frequency.
-100	Error in terrain ray trace *(contact the APM CSCI developers if this occurs)*
115	*WARNING*: Antenna height with respect to mean sea level is greater than the last height in the refractivity profile at the source.

The APM CSCI provides propagation loss and factor for all heights and ranges when running in a full hybrid mode. When running in a partial hybrid mode, it provides propagation loss and factor for limited heights and angles. Finally, it will also be limited in both height and angle coverage when running in a PE-only mode. Refer to Section 7.1 for environmental conditions under which each execution mode is automatically selected.

Absorption by atmospheric gases (oxygen and water vapor) may be important to some applications of the APM CSCI and is controlled by specifying a non-zero value for the absolute humidity, abs_{hum}, and the surface air temperature, t_{air}; or likewise, specifying a non-zero value for the gaseous absorption attenuation rate, γ_a.

A particular application of the APM CSCI may or may not require the consideration of troposcatter effects within the propagation loss calculations. For example, a radar evaluation most likely would not be influenced by troposcatter; while an ESM evaluation would. APM has the feature of including or not including the troposcatter calculation by setting a logical flag called T_{ropo}. Setting this flag to '.false.' would omit the calculation. Setting this flag to '.true.' would include the calculation. For the APM CSCI implementation in external coverage and loss diagram applications, T_{ropo} must be set equal to '.true.' so as to include the calculation.

APM, by default, will run in an "automatic" mode in which, depending upon user-specified inputs, will choose the appropriate sub-models to use for a particular application. However, by setting the logical flag PE_{flag} to '.true.', APM will be forced to use only the PE sub-model for a particular external application. By default, this flag is set to '.false.'. If this flag is '.true.', then the visible portion of the maximum PE propagation angle, th_{max} (i.e., the maximum propagation angle the PE algorithm will accommodate in the field calculations), and the parameter, r_{mult}, must be specified. By default, r_{mult} is equal to 1; however, th_{max} does not have a default value and must be explicitly defined. The parameter r_{mult} is a range step multiplier that allows the user to vary the PE range step from the default calculated.

Use this option with caution, as you must have some basic knowledge of PE algorithms and how they work to input proper combinations of maximum calculation angles and range steps for a given frequency. *When using this option, most error checking is bypassed and parameter limits can be over-ridden. Erroneous field values may result if a poorly chosen combination of* th_{max} *and* r_{mult} *are used.*

APM Ver. 2.1.04 has the capability of determining and providing to the main calling program direct and reflected propagation angles, as well as the propagation factor from both direct and reflected rays. Note that these quantities are obtained only from the FE and RO sub-models within APM. It does not compute the angles and propagation factors for the separate rays within the split-step PE and XO sub-models, but does provide the resultant propagation angle and factor within these regions. This information is returned if the logical flag *lang* is set to '.true.'; however, do not enable this feature if any portion of the propagation path is over land. The computation is valid only when the propagation path is entirely over water.

5. CSCI DETAILED DESIGN

A description of each component of the APM CSCI is provided in the following subsections.

5.1 ADVANCE PROPAGATION MODEL INITIALIZATION (APMINIT) CSC

The APMINIT CSC interfaces with various SUs for the complete initialization of the APM CSCI.

Upon entering the APMINIT CSC, several variables are initialized. All internal logical flags controlling certain environmental calculations and errors are initialized.

The wind speeds and ranges are checked to see if they fall within the specified bounds. If not, then an error is returned.

The variables and arrays necessary for rough surface and clutter calculations are initialized and checked for valid values.

Next, the absorption calculation flag, k_{abs}, is set to 1 if the air temperature, t_{air}, or the absolute humidity, abs_{hum}, are non-zero. If an attenuation rate is specified ($\gamma_a \neq 0$), then k_{abs} is set to 2. If the user specifies t_{air} and abs_{hum} to be 0, then k_{abs} is set equal to 0, in which case, no absorption losses are computed.

Next, if running the APM CSCI under the hybrid mode (PE_{flag} = '.false.'), then the antenna height, the maximum output range, r_{max}, the maximum output height, h_{max}; and the minimum output height, h_{min}, are checked for valid numerical values. If the antenna height is below 1.5 m then i_{error} is set to –41 and the APMINIT CSC is exited. r_{max} is set to the value specified from the calling CSCI or 5000 m, whichever is greater; and h_{max}, is set to the value specified from the calling CSCI or 100 m, whichever is greater. If h_{min} is greater than h_{max}, then i_{error} is set to -42 and the APMINIT CSC is exited. If the maximum output range and minimum and maximum output height values are valid, then the APMINIT CSC proceeds to the next step.

The atmospheric volume must be "covered" or resolved with a mesh of calculation points that will, as a matter of routine, exceed the height/range resolution requirements of the particular application of the APM CSCI. The height and range mesh size per APM CSCI output point, Δz_{out} and Δr_{out}, respectively, are calculated from the number of APM output points and the maximum range and height as follows:

$$\Delta r_{out} = \frac{r_{max}}{n_{rout}},$$

$$\Delta z_{out} = \frac{h_{max} - h_{min}}{n_{zout}}.$$

The number of terrain range/height pairs, i_{tpa}, used for internal calculations is initialized to 1 plus the user-specified number of range/height pairs, i_{tp}. The ALLARRAY_APM SU is then referenced to dynamically allocate and initialize all arrays associated with terrain, refractivity, troposcatter, and general variable arrays. If an error has occurred while allocating memory, i_{error} is returned with a non-zero value and the CSC is exited; otherwise, the CSC proceeds to the next step.

Next, the constants used to determine the antenna pattern factor are computed. First, if a user-defined height-finder antenna pattern has been specified (i_{pat} = 6), along with power cut-back angles and factors, then the angles are converted to radians and stored in array *hfangr*. If the cut-back angles are not steadily increasing, i_{error} is set to -7 and the CSC is exited; otherwise, the CSC proceeds with the next step.

If a directional antenna pattern has been specified, the antenna vertical beamwidth in degrees, μ_{bw}, is checked for extremely small beamwidth values. If the value is less than or equal to 10^{-4}, i_{error} is set to -10 and the CSC is exited; otherwise, the CSC proceeds with the next step.

The antenna beamwidth and elevation angles are converted to radians (μ_{bwr} and μ_{or}, respectively) and the variables, ant_{fac} and μ_{max}, for use in the ANTPAT SU are determined as follows.

If the antenna pattern is Gaussian (i_{pat}=2), then ant_{fac} is given by

$$ant_{fac} = \frac{.34657359}{\left[\mathbf{SIN}\left(\frac{\mu_{bwr}}{2}\right)\right]^2}\ .$$

If the antenna pattern is Sin(X)/X (i_{pat} = 3), or a generic height finder (i_{pat} = 5), then ant_{fac} is given by

$$ant_{fac} = \frac{1.39157}{\mathbf{SIN}\left(\frac{\mu_{bwr}}{2}\right)}\ ,$$

and μ_{max} is given by

$$\mu_{max} = \mathbf{TAN}^{-1}\left(\frac{\pi}{ant_{fac}\sqrt{1-\left(\frac{\pi}{ant_{fac}}\right)^2}}\right).$$

If running the APM CSCI in hybrid mode, the antenna height is next checked for a valid height based on the combination of frequency and beamwidth specified. The antenna height must not be less than the radius of the antenna and is bounded by

$$ant_{ht} \geq \text{maximum of}\left(1.5, .6\frac{c_o}{f_{mhz}\ \mu_{bw}}\right),$$

where c_o is the speed of light (299.79×10^6 m/s).

Next, the TERINIT SU is referenced to initialize all terrain profile and associated arrays. If an error has occurred while in the TERINIT SU, i_{error} is returned with a non-zero value and the CSC is exited; otherwise, the CSC proceeds with the next step.

If vertical polarization and/or rough surface calculations are required (i.e., a non-zero wind speed is specified) then the flag, i_{alg}, indicating which DMFT algorithm to use, is set to 1 (central difference) for frequencies less than 400 MHz, and is set to 2 (backward difference) for frequencies greater than 400 MHz. The default value for i_{alg} is 0, in which case, no DMFT algorithm is used for the particular APM application.

Arrays containing all output ranges, *rngout*, 20 times the logarithm of all output ranges, *rlogo*, and the square of the output ranges, *rsqrd*, are initialized according to

$$\left.\begin{aligned} rngout_i &= i\,\Delta r_{out}\,, \\ rlogo_i &= 20\,\mathbf{LOG}_{10}\left(i\,\Delta r_{out}\right), \\ rsqrd_i &= \left(i\,\Delta r_{out}\right)^2. \end{aligned}\right. \qquad i = 1, 2, \ldots n_{rout}$$

The minimum power of 2 transform, ln_{min}, is next initialized to 10. If the PE-only option is not activated (PE_{flag} = '.false.'), then the execution mode in which the APM CSCI will operate is determined. Based on inputs, it determines whether to use the airborne hybrid mode (i_{hybrid}=0), full hybrid mode (i_{hybrid}=1), or partial hybrid mode (i_{hybrid}=2). For antenna heights greater than 100 m above the local ground height, i_{hybrid} is set equal to 0. For antenna heights less than 100 m, i_{hybrid} is initialized to 1. If performing a terrain case (f_{ter}='.true.') and the first 2500 m of the terrain profile is not flat, then i_{hybrid} is set equal to 2. If running in full hybrid mode (i_{hybrid}=1) then the ALLARRAY_RO SU is referenced to allocate and initialize all arrays associated with RO calculations.

The variable y_{fref} is initialized to 0. If a terrain profile has been specified (f_{ter}='.true.') then y_{fref} is set equal to ty_1. Next, the output height arrays *zout* and *zro* are initialized as follows:

$$\left.\begin{aligned} zout_i &= hm_{ref} + i\,\Delta z_{out} \\ zro_i &= zout_i - y_{fref} \end{aligned}\right\}; \quad i = 1, 2, \ldots\ldots n_{zout}\,,$$

where the variables ty_1 and hm_{ref} are obtained from the TERINIT SU.

Next, the REFINIT SU is referenced to initialize all refractivity associated arrays. If an error has occurred while in the REFINIT SU, i_{error} is returned with a non-zero value and the CSC is exited; otherwise, the CSC proceeds to the next step.

If the PE-only option is activated (PE_{flag} = '.true.'), then the minimum height for the PE calculation region z_{test} is set equal to ht_{lim}. If the PE-only option is not activated (PE_{flag} = '.false.'), then output height arrays used in FE calculations are computed:

$$\left.\begin{aligned} zoutma_i &= zout_i - ant_{ref} \\ zoutpa_i &= zout_i - y_{fref} + ant_{ref} \end{aligned}\right\}; \quad i = 1, 2, \ldots n_{zout}\,.$$

The limiting grazing angle, ψ_{lim}, is computed as

$$\psi_{lim} = \mathbf{MAX}\left(.002, \frac{.04443}{f_{MHz}^{.3333}}\right).$$

If more than one refractivity profile has been specified ($n_{prof} > 1$), then ψ_{lim} is multiplied by 2. It is then adjusted for trapping effects by

$$\psi_{lim} = \psi_{lim} + \sqrt{\left|2\left(rm_{max} - rm_{min}\right)\right|} ,$$

where rm_{max} and rm_{min} are determined in the REFINIT SU. The RO elevation angle limit, α_{lim}, is given by

$$\alpha_{lim} = \sqrt{\left|\psi_{lim}^2 + 2\left(rm_{tx} - refdum_0\right)\right|} ,$$

where the variable rm_{tx} and array $refdum$ are determined in the REFINIT SU. Next, the height tolerance, z_{tol} is initialized to 0.05 and the range and index variables for the RO region, i_{ROp} and x_{ROn}, are initialized to -1 and 0, respectively. The minimum height for the PE calculation region is determined next. The minimum height encompassing all trapping refractive layers is given by

$$h_{test} = h_{trap} + h_{thick} ,$$

where h_{trap} and h_{thick} are determined in the REFINIT SU. If running in full hybrid mode (i_{hybrid}=1), the minimum height for the PE calculation region is given by

$$z_{test} = \mathbf{MAX}\left(h_{test}, 1.2\, h_{termax}\right),$$

where h_{termax} is determined in the TERINIT SU. If running in either the partial hybrid mode or PE-only mode, z_{test} is then given by

$$z_{test} = \mathbf{AMAX}\left(ht_{lim}, ant_{ref}\right).$$

The tangent angle, a_{test}, used for automatic calculation of the maximum propagation angle, is given by

$$a_{test} = \mathbf{TAN}^{-1}\left(\frac{z_{test} + ant_{ref} + \dfrac{r_{max}^2}{2a_{ekst}}}{r_{max}}\right),$$

with α_{lim} is now set equal to the greater of a_{test} or the previously determined α_{lim}, and a_{ekst} is $4/3$ times the mean earth's radius. The GET_K SU is then referenced to determine the effective earth's radius factor.

If the grazing angles need to be computed for rough surface and clutter calculations then the wavelength, λ, and the free-space wavenumber, k_o, are initialized using a fixed frequency of 10 GHz (f_{rqg}):

$$\lambda = \frac{c_o}{f_{rqg}}, \; k_o = \frac{2\pi}{\lambda} .$$

The maximum PE calculation angle is set equal to the greater of 4° (*thmxg)* or the maximum terrain tangent angle, α_u, determined in TERINIT SU. The FFTPAR SU is then referenced to determine PE grid variables and the transform size required. Next, the PEINIT SU is referenced to initialize all arrays and variables associated with the PE calculation algorithm. Variables needed for spectral estimation of the grazing angles are then initialized. The number of bins, n_p, considered in the near-surface PE region, is set equal to 16. The power of 2 transform, ln_p, is set equal to 9. The following variables used in the spectral estimation calculations are given by

$$n_s = 2^{ln_p},$$
$$n_{p4} = \frac{n_p}{4},$$
$$n_{p34} = 3n_{p4},$$
$$cn_{p75} = \frac{\pi}{n_{p4}}.$$

The ALLARRAY_XORUF SU is then referenced to allocate and initialize all arrays associated with rough surface calculations. The filter array *filtp* is now determined by

$$filtp_i = 1/2 + 1/2 \cos(i\, cn_{p75}); \quad i = 0, 1, 2, \ldots n_{p4},$$

and the variable xo_{con} is given by

$$xo_{con} = \frac{\lambda}{2 n_s \Delta z_{PE}} .$$

The GETANGLES SU is next referenced to determine all grazing angles and/or propagation angles, if desired, for subsequent rough surface calculations. This involves computing a complete PE run out to the maximum range, r_{max}. In doing this, the

refractivity arrays initially set in the REFINIT SU must be re-initialized for the second, or "real", PE run that includes rough surface effects.

If rough surface calculations are not required (ruf = '.false.') then the grazing angle array Ψ is initialized to 0, with the number of grazing angles, i_{grz}, set to 1.

Next, the wavelength and free-space wavenumber are recomputed for the specified frequency f_{MHz}:

$$\lambda = \frac{c_o}{f_{MHz}}, \; k_o = \frac{2\pi}{\lambda}.$$

The DIEINIT SU is then referenced to initialize all dielectric ground constants. If rough surface calculations are required, two terms used in the computation of the rough surface reflection coefficient are determined as follows:

$$\begin{aligned} ruf_{fac} &= \frac{4\pi\,(.0051)}{\lambda} \\ ruf_{ht} &= ruf_{fac}\; wind_1^2 \end{aligned},$$

where $wind_1$ is the first wind speed in m/s provided by the calling CSCI.

If the PE-only option is activated (PE_{flag} = '.true.') and the frequency specified is greater or equal to 50 MHz, then the maximum propagation calculation angle used in the PE region, Θ_{max}, is determined according to

$$\Theta_{max} = \tfrac{4}{3}\, th_{max}.$$

The minimum transform size is then set to ln_{min} plus 1 for every 5° in Θ_{max}. For frequencies less than 50 MHz (HF_{flag} = '.true.'), Θ_{75} and Θ_{max} are defined as

$$\begin{aligned} \Theta_{75} &= \mathrm{MAX}\left(2\, slp_{max}, 40°\right) \\ \Theta_{max} &= \mathrm{MIN}\left(\tfrac{4}{3}\Theta_{75}, 80°\right) \end{aligned},$$

where slp_{max} is the maximum of the terrain slope along the path. If no terrain is specified, then Θ_{75} is set equal to 20º. The FFTPAR SU is then referenced to determine the PE grid variables and the maximum valid height within the PE calculation region, z_{lim}, is set equal to the smaller of z_{test} and ht_{lim}. The PEINIT SU is then referenced to initialize all PE variables and arrays and, if required (i.e., i_{alg} > 0), the ALN_INIT SU is referenced to initialize all arrays and variables used in the surface impedance calculations.

If the PE-only option is not activated (PE_{flag} = '.false.') and if using the airborne hybrid mode (i_{hybrid}=0), then the maximum PE calculation angle is determined from Θ_{75}, obtained from the GET_K SU, according to

$$\Theta_{max} = \tfrac{4}{3}\Theta_{75} ,$$

and the minimum transform size is set to ln_{min} plus 1 for every 5° in Θ_{max}. The FFTPAR SU is then referenced to determine the PE grid variables and the maximum valid height within the PE calculation region, z_{lim}, is set equal to z_{test}. If the airborne mode is not the mode of execution ($i_{hybrid}\neq 0$), then the GETTHMAX SU is referenced to determine the minimum angle Θ_{75} to use within the PE calculation region. z_{lim} is then set equal to the smaller of z_{lim} and ht_{lim}.

To determine if XO calculations are required, the following steps 1 through 6 are performed for i_{hybrid} not equal to 0.

1. If z_{lim} is less than ht_{lim}-10^{-5}, then the SU proceeds with steps 2 through 6. Otherwise, these steps are skipped and the output range and index, r_{atz} and i_{ratz}, respectively, are calculated as

$$\begin{aligned} r_{atz} &= 2\, r_{max}, \\ i_{ratz} &= n_{rout} + 1 \end{aligned}.$$

2. The bin number jz_{lim}, corresponding to z_{lim}, is given by

$$jz_{lim} = \mathbf{INT}\left(\frac{z_{lim}}{\Delta z_{PE}} \right),$$

   and z_{lim} is recomputed such that it corresponds to an integer multiple of bins or mesh heights: $z_{lim}= jz_{lim}\, \Delta z_{PE}$.

3. Next, r_{atz} and i_{ratz} are determined based on the height, angle, and range arrays *htemp*, *raya*, and *rtemp*, previously determined in the GETTHMAX SU. First, the index *j* is initialized to i_{ap} (previously determined in the GETTMAX SU) and the index *id* is initialized to 1. Steps 3.a through 3.b are repeated until *j* is greater than i_{rtemp}.

   a. If $htemp_j$ is greater than z_{lim}, then the iteration is ended and the SU proceeds with step 4.

b. If $htemp_j$ is greater than zrt_{id}, then id is incremented by 1. The index j is now incremented by 1. Steps 3a through 3b are then repeated.

4. The index ira is set equal to the greater of 1 or j-1; the index idg is set equal to id-1; and the gradient g_{rd} is set equal to gr_{idg}.

5. Next, the ray with initial launch angle a_{launch} is traced from height $htemp_{ira}$ to z_{lim}. The square of the local ray angle, rad, at the end of the ray trace step is given by

$$rad = raya_{ira}^2 + 2\, g_{rd} \left(z_{lim} - htemp_{ira}\right).$$

The local ray angle, a_{atz}, at height z_{lim} is initialized to 0. If rad is greater than 0, then a_{atz} is given by

$$a_{atz} = \mathbf{SIGN}\left(1, raya_{ira}\right)\sqrt{rad}\ ,$$

and the range r_{atz} is now given by

$$r_{atz} = rtemp_{ira} + \frac{a_{atz} - raya_{ira}}{g_{rd}}\ .$$

6. If r_{atz} is less than r_{max} and z_{lim} is less than ht_{lim}, then the index k is determined such that $rngout_{k\text{-}1} < r_{atz} < rngout_k$. Then i_{ratz} is set equal to the smaller of n_{rout} and k, and i_{xostp} is set equal to i_{ratz}. The number of XO calculations needed, i_{xo}, is then set equal to i_{xostp}.

The PEINIT SU is next referenced to initialize all variables and arrays necessary for PE calculations. All variables and arrays associated with XO calculations are now initialized, provided i_{xo} is greater than 0. The maximum number of points, iz_{max}, allocated for arrays used in XO calculations, is determined by

$$iz_{max} = \frac{\mathbf{NINT}\left(\dfrac{r_{max} - r_{atz}}{\Delta r_{PE}}\right)}{iz_{inc}} + 4\ .$$

Next, variables needed for spectral estimation calculations are initialized. The number of bins, n_p, considered in the upper PE region, is set equal to 8 if no terrain profile or wind speeds are specified, and 16, otherwise. The power of 2 transform, ln_p, is set equal to 8.

The following variables are given by

$$n_s = 2^{ln_p},$$
$$n_{p4} = \frac{n_p}{4},$$
$$n_{p34} = 3n_{p4},$$
$$cn_{p75} = \frac{\pi}{n_{p4}}.$$

The ALLARRAY_XORUF SU is then referenced to allocate and initialize all arrays associated with XO calculations. The filter array *filtp* is now determined by

$$filtp_i = \tfrac{1}{2} + \tfrac{1}{2}\,\mathbf{COS}\left(i\,cn_{p75}\right); \quad i = 0, 1, 2, \ldots n_{p4},$$

and the variable xo_{con} is given by

$$xo_{con} = \frac{\lambda}{2\,n_s \Delta z_{PE}}$$

The ALN_INIT SU is next referenced to initialize all arrays and variables used in the surface impedance calculations and the FILLHT SU is referenced to obtain the *htfe* array separating the FE from the RO region.

Several variables associated with the beginning, middle, and end of a PE range step, are initialized. If grazing angles were computed, the GRAZE_INT SU is referenced to interpolate the angles (as determined in the GETANGLES SU) at every output range step. If troposcatter calculations are required (T_{ropo} = 1), then the TROPOINIT SU is referenced to initialize all variables and arrays. An additive loss term pl_{cnst} and the free space loss *fsl* are determined at each output range step by

$$\begin{aligned} pl_{cnst} &= 20\,\mathbf{LOG_{10}}\left(2\,k_o\right), \\ fsl_i &= rlogo_i + pl_{cnst} \;; \quad i = 1, 2, \ldots.. n_{rout} \end{aligned}.$$

Finally, if the absorption flag k_{abs} is equal to 1, then the GASABS SU is referenced to determine the absorption attenuation rate, gas_{att}. If k_{abs} is equal to 2, then gas_{att} is determined by the calling CSCI-specified attenuation rate, γ_a, multiplied by 10^{-3} to convert γ_a from dB/km to dB/m. Several dynamically allocated terrain arrays used in the TERINIT SU are deallocated and the CSC is exited. Table 8 and Table 9 provide identification, description, unit of measure, and the computational source for each APMINIT CSC input and output data element.

Table 8. APMINIT CSC input data element requirements.

Name	Description	Units	Source
abs_{hum}	Absolute humidity near the surface	g/meters^3	Calling CSCI
a_{ekst}	$\frac{4}{3}$ times mean earth radius	meters	APM_MOD
G	Gain of transmit/receive antennas	dBi	Calling CSCI
ant_{ht}	Transmitting antenna height above local ground	meters	Calling CSCI
c_o	Speed of light multiplied by 10^{-6}	meters/sec	APM_MOD
C_{lut}	Clutter calculation flag: '.false.' = do not compute surface clutter '.true.' = compute surface clutter	N/A	Calling CSCI
$dielec$	Two-dimensional array containing the relative permittivity and conductivity; $dielec_{1,i}$ and $dielec_{2,i}$, respectively.	N/A, S/m	Calling CSCI
f_{MHz}	Frequency	MHz	Calling CSCI
γ_a	Gaseous absorption attenuation rate	dB/km	Calling CSCI
γc	Array of "backscattering effectiveness" values used in computing the reflectivity over land	dB	Calling CSCI
γrng	Array of corresponding ranges for each γc value	meters	Calling CSCI
$hfang$	Cut-back angles	degrees	Calling CSCI
$hffac$	Cut-back antenna pattern factors	N/A	Calling CSCI
h_{max}	Maximum output height with respect to mean sea level	meters	Calling CSCI
h_{min}	Minimum output height with respect to mean sea level	meters	Calling CSCI
$hmsl$	Two-dimensional array containing heights with respect to mean sea level of each profile. Array format must be $hmsl_{i,j}$ = height of i^{th} level of j^{th} profile; j=1 for range-independent cases	meters	Calling CSCI
i_{extra}	Extrapolation flag for refractivity profiles entered in combination with terrain below below mean sea level 0 = extrapolate to minimum terrain height standard atmosphere gradient 1= extrapolate to minimum terrain height using first gradient in profile	N/A	Calling CSCI
i_{gc}	Number of γc values specified	N/A	Calling CSCI
i_{gr}	Number of different ground types specified	N/A	Calling CSCI
$igrnd$	Integer array containing ground type composition for given terrain profile - can vary with range. Different ground types are: 0 = seawater 1 = freshwater 2 = wet ground 3 = medium dry ground 4 = very dry ground 5 = ice at -1 degree C 6 = ice at -10 degree C 7 = user-defined (in which case, values of relative permittivity and conductivity must be given)	N/A	Calling CSCI

Table 8. APMINIT CSC input data element requirements (continued).

Name	Description	Units	Source
i_{pat}	Antenna pattern type 1 = Omnidirectional 2 = Gaussian 3 = Sine(x)/x 4 = Cosecant-squared 5 = Generic height-finder 6 = User-defined height-finder 7 = User-defined antenna patter	N/A	Calling CSCI
i_{pol}	Polarization flag: 0 = horizontal polarization 1 = vertical polarization	N/A	Calling CSCI
i_{rtemp}	Temporary number of range steps (used for ray tracing)	N/A	APM_MOD
i_{tp}	Number of height/range points in profile	N/A	Calling CSCI
lang	Propagation angle and factor output flag '.true.'= Output propagation angle and propagation factor for direct and reflected ray (where applicable). '.false.' = Do not output propagation angles and factors	N/A	Calling CSCI
lerr6	Logical flag to allow for error -6 to be bypassed	N/A	Calling CSCI
lerr12	Logical flag to allow for error -12 to be bypassed	N/A	Calling CSCI
L_{sys}	Miscellaneous system losses	dB	Calling CSCI
lvlp	Number of levels in refractivity profile	N/A	Calling CSCI
N_f	Noise figure	dB	Calling CSCI
n_{facs}	Number of user-defined cut-back angles and cut-back antenna factors for user specified height-finder antenna type	N/A	Calling CSCI
n_{prof}	Number of refractivity profiles	N/A	Calling CSCI
n_{rout}	Number of output range points desired	N/A	Calling CSCI
n_w	Number of wind speeds	N/A	Calling CSCI
n_{zout}	Number of output height points desired	N/A	Calling CSCI
n_{zout_rtg}	Number of output receiver heights specified relative to the local surface elevation.	N/A	Calling CSCI
PE_{flag}	Flag to indicate use of PE algorithm only: '.true.' = only use PE sub-model '.false.' = use automatic hybrid model	N/A	Calling CSCI
pi	Constant equal to the value of π	N/A	APM_MOD
P_t	Transmitter peak power	kW	Calling CSCI
refmsl	Two-dimensional array containing refractivity with respect to mean sea level of each profile. Array format must be $refmsl_{i,j}$ = M-unit at i^{th} level of j^{th} profile; j=1 for range-independent cases	M-units	Calling CSCI
rgrnd	Array containing ranges at which varying ground types apply	meters	Calling CSCI

Table 8. APMINIT CSC input data element requirements (continued).

Name	Description	Units	Source
r_{max}	Maximum specified range	meters	Calling CSCI
r_{mult}	PE range step multiplication factor	N/A	Calling CSCI
$rngprof$	Ranges of each profile: $rngprof_i$ = range of i^{th} profile	meters	Calling CSCI
$rngwind$	Ranges of wind speeds entered: $rngwind_i$ = range of i^{th} wind speed	meters	Calling CSCI
t_{air}	Air temperature near the surface	°C	Calling CSCI
$terx$	Range points of terrain profile	meters	Calling CSCI
$tery$	Height points of terrain profile	meters	Calling CSCI
$zout\_rtg$	Array of output receiver heights specified relative to the local surface elevation.	meters	Calling CSCI
th_{max}	Visible portion of maximum PE calculation angle	degrees	Calling CSCI
θ_{hbw}	Horizontal beamwidth	degrees	Calling CSCI
τ	Pulse length/width	μsec	Calling CSCI
T_{ropo}	Troposcatter calculation flag: ‘.false.’= no troposcatter calcs ‘.true.’ = troposcatter calcs	N/A	Calling CSCI
μ_{bw}	Antenna vertical beamwidth	degrees	Calling CSCI
μ_o	Antenna elevation angle	degrees	Calling CSCI
$wind$	Array of wind speeds	meters/ sec	Calling CSCI
$wind_{dir}$	Angle between antenna boresight and upwind direction	degrees	Calling CSCI

Table 9. APMINIT CSC output data element requirements.

Name	Description	Units
a_{atz}	Local ray or propagation angle at height z_{lim} and range r_{atz}	radians
a_{launch}	Launch angle used which, when traced, separates PE and XO regions from the RO region	N/A
α_{lim}	Elevation angle of the RO limiting ray	radians
ant_{fac}	Antenna pattern parameter (depends on i_{pat} and μ_{bw})	N/A
Δr_{out}	Output range step	meters
Δz_{out}	Output height increment	meters
$filtp$	Array filter for spectral estimation calculations	N/A
fsl	Free space loss array for output ranges	dB
f_{ter}	Logical flag indicating if terrain profile has been specified: ‘.true.’ = terrain profile specified ‘.false.’ = terrain profile not specified	N/A
gas_{att}	Gaseous absorption attenuation rate	dB/m

Table 9. APMINIT CSC output data element requirements. (continued)

Name	Description	Units
$hfangr$	Antenna pattern cut-back angles (for specific height finder, or user-defined antenna patterns)	radians
HF_{flag}	HF computation flag indicating the frequency specified is less than 50 MHz	N/A
i_{alg}	Integer flag indicating which DMFT algorithm is being used: 0 = no DMFT algorithm will be used 1 = use central difference algorithm 2 = use backward difference algorithm	N/A
i_{error}	Error flag	N/A
i_{hybrid}	Integer indicating which sub-models will be used: 0 = airborne hybrid model (FEDR + PE) 1 = full hybrid model (PE + FE + RO + XO) 2 = partial hybrid model (PE + XO)	N/A
i_{ratz}	Index of output range step in which to begin storing propagation factor and outgoing angle for XO region	N/A
i_{ROp}	Array index for previous range in RO region	N/A
i_{tpa}	Number of height/range points pairs in terrain profile arrays tx, ty	N/A
i_{xo}	Number of range steps in XO calculation region	N/A
i_{xostp}	Current output range step index for XO calculations	N/A
iz_{max}	Maximum number of points allocated for arrays associated with XO calculations	N/A
jz_{lim}	PE bin # corresponding to z_{lim}, i.e., $z_{lim} = jz_{lim}\ \Delta z_{PE}$	N/A
k_{abs}	Gaseous absorption calculation flag: 0 = no absorption loss 1 = compute absorption loss based on air temperature t_{air} and absolute humidity abs_{hum} 2 = compute absorption loss based on specified absorption attenuation rate γ_a	N/A
k_o	Free-space wavenumber	meters^{-1}
λ	Wavelength	meters
ln_{min}	Minimum power of 2 transform size	N/A
ln_p	Power of 2 transform size used in spectral estimation calculations; i.e., $n_p = 2^{ln_p}$	N/A
$lrtg$	Logical flag indicating if loss relative to the local ground height needs to be computed '.true.' = Compute loss relative to ground at heights specified by array $zout\_rtg$ '.false.' = Do not compute loss	N/A
μ_{or}	Antenna pattern elevation angle	radians
μ_{bwr}	Antenna vertical beamwidth in radians	radians
μ_{max}	Limiting angle for SIN(X)/X and generic height finder antenna pattern factors	N/A
n_p	Number of bins in upper and near-surface PE region to consider for spectral estimation	N/A
n_{p34}	¾ n_p	N/A

Table 9. APMINIT CSC output data element requirements. (continued)

Name	Description	Units
n_{p4}	¼ n_p	N/A
n_s	Transform size for spectral estimation calculations	N/A
pl_{cnst}	Constant used in determining propagation loss ($pl_{cnst} = 20 \log_{10}(2\ k_o)$)	dB/m
ψ_{lim}	Grazing angle of limiting ray	radians
r_{atz}	Range at which z_{lim} is reached (used for hybrid model)	meters
rlogo	Array containing 20 times the logarithm of all output ranges	N/A
rngout	Array containing all desired output ranges	meters
rsqrd	Array containing the square of all desired output ranges	meters^2
ruf	Logical flag indicating if rough sea surface calculations are required '.true.' = perform rough sea surface calculations '.false.' = do not perform rough sea surface calculations	N/A
ruf_{fac}	Factor used for wave height calculation	meters^{-1}
ruf_{ht}	RMS sea surface wave height multiplied by $2k_o$	meters^{-1}
Θ_{max}	Maximum propagation angle used in PE calculations	radians
Θ_{75}	75% of maximum propagation angle in PE calculations	radians
xo_{con}	Constant used in determining outgoing propagation angle ϑ_{out}	N/A
y_{fref}	Ground elevation height at source	meters
xROn	Next range in RO region	meters
z_{lim}	Height limit for PE calculation region	meters
zout	Array containing all desired output heights referenced to h_{minter}	meters
zoutma	Array output heights relative to "real" ant_{ref}	meters
zoutpa	Array output heights relative to "image" ant_{ref}	meters
zro	Array of output heights in RO region	meters
z_{test}	Height in PE region that must be reached for hybrid model	meters
z_{tol}	Height tolerance for Newton's method	meters

5.1.1 Allocate Arrays APM (ALLARRAY_APM) SU

The ALLARRAY_APM SU allocates and initializes all dynamically dimensioned arrays associated with the APM terrain, refractivity, troposcatter, and general variable arrays.

The ALLARRAY_APM SU utilizes the FORTRAN ALLOCATE and DEALLOCATE statements to dynamically size arrays that have been previously declared with the ALLOCATABLE attribute in the APM_MOD MODULE or to free the array storage space previously reserved in an ALLOCATE statement. Each dimension of the ALLOCATABLE array is indicated by a colon in the APM_MOD module (e.g., *array*(:)). The ALLOCATE statement establishes the upper and lower bounds of each dimension and reserves sufficient memory. Because attempting to allocate a previously

allocated array causes a run-time error, each ALLOCATE statement for an array is preceded by a test to determine if it has been allocated. If it has, it is deallocated before it is allocated.

Initially, the integer used to indicate an error, i_{error}, is set to zero. If, in attempting to allocate an array, a value of i_{error} other than zero is returned by an ALLOCATE statement, the SU is exited. Note that each array that is dynamically allocated in this SU is initialized to zero.

Seven integers input to this SU are used to dynamically allocate the arrays. Unless otherwise indicated, these integers are used as the single dimension of the dynamically allocated array. The first, i_{gc}, is the number of γc values specified, describing the backscattering effectiveness of the surface. The second, i_{gr}, is the number of different ground types specified. The third, i_{tpa}, is the number of terrain points used internally in arrays *tx* and *ty*. The fourth, *lvlp*, is the number of levels in the refractivity profile. The fifth, n_{facs}, is the number of user-defined cut-back antenna pattern factors for the user-defined height-finder antenna type. The sixth, n_{rout}, is the integer number of output range points desired. And finally, the seventh, n_{zout}, is the integer number of output height points desired.

The definitions of the following arrays allocated in this SU are given in Table 11. The only array that is allocated using the integer n_{facs} is *hfangr*. The arrays that are allocated using the integer n_{rout} are *ffat1m*, *rsqrd*, *fsl*, *rlogo*, *hlim*, *htfe*, *zxo*, and *rngout*. The arrays that are allocated using the integer n_{zout} are *zout*, *zoutma*, *zoutpa*, *rfac1*, *rfac2*, and *rloss*. Only those arrays associated with the hybrid mode of execution will be allocated; i.e., if the PE-only mode is activated (PE_{flag} = '.false'), then arrays *rsqrd, zoutma, zoutpa, hlim,* and *htfe* will not be allocated.

The arrays associated with terrain information use the integers i_{tpa}, i_{gc}, or i_{gr}. The arrays that are allocated with the integer i_{tpa} are *tx*, *ty*, and *slp*. The arrays allocated using the integer i_{gr} are *igrnd*, *rgrnd*, and nc^2, and those arrays allocated with size i_{gc} are γc and γrng. The array *dielec* is allocated using two as the first dimension and i_{gr} as the second dimension. While arrays *igrnd*, *rgrnd*, and *dielec* are usually specified by the calling CSCI, it is not necessary when performing an over-water case. In this case, i_{gr} can have a value of 0 and these arrays will be defaulted to the size of one element with a sea-surface ground type.

All refractivity arrays used in the PE algorithm are allocated using the integer *lvlp* and include *refdum, htdum, grdum, href*, and *refref*.

The arrays associated with troposcatter calculations use either integers n_{zout} and n_{rout} and will be allocated only if troposcatter calculations are required for the particular APM CSCI application (T_{ropo} = '.true.'). The arrays allocated using the integer n_{zout} include *adif, d2s, rdt,* and $\vartheta 2s$, and the array allocated for size, n_{rout}, is $\vartheta 0$.

Table 10 and Table 11 provide identification, description, units of measure, and the computational source for each ALLARRAY_APM SU input and output data element.

Table 10. ALLARRAY_APM SU input data element requirements.

Name	Description	Units	Source
C_{lut}	Clutter calculation flag: '.false.' = do not compute surface clutter '.true.' = compute surface clutter	N/A	Calling CSCI
i_{gc}	Number of γc values specified	N/A	Calling CSCI
i_{gr}	Number of different ground types specified	N/A	Calling CSCI
i_{tpa}	Number of terrain points used internally in terrain profile arrays tx, ty	N/A	APMINIT CSC
$lang$	Propagation angle and factor output flag '.true.'= Output propagation angle and propagation factor for direct and reflected ray (where applicable). '.false.' = Do not output propagation angles and factors	N/A	Calling CSCI
$lvlp$	Number of levels in refractivity profile	N/A	Calling CSCI
n_{facs}	Number of user-defined cut-back angles and cut-back antenna factors for user specified height-finder antenna type	N/A	Calling CSCI
n_{rout}	Number of output height points desired	N/A	Calling CSCI
n_{zout}	Number of output range points desired	N/A	Calling CSCI
PE_{flag}	Flag to indicate use of PE algorithm only: '.true.' = only use PE sub-model '.false.' = use automatic hybrid mode	N/A	Calling CSCI
T_{ropo}	Troposcatter calculation flag: '.false.'= no troposcatter calcs '.true.' = troposcatter calcs	N/A	Calling CSCI

Table 11. ALLARRAY_APM SU output data element requirements.

Name	Description	Units
$adif$	Height differences between ant_{ref} and all output receiver heights	meters
$d2s$	Array of tangent ranges for all output receiver heights over smooth surface	meters
$dielec$	Two-dimensional array containing the relative permittivity and conductivity; $dielec_{1,i}$ and $dielec_{2,i}$, respectively.	N/A, S/m
$ffat1m$	Propagation factor array computed at 1 m above the surface.	dB
fsl	Free space loss array for output ranges	dB
γc	Array of "backscattering effectiveness" values used in computing the reflectivity over land	dB
γrng	Array of corresponding ranges for each γc value	meters

Table 11. ALLARRAY_APM SU output data element requirements. (continued)

Name	Description	Units
grdum	Array of refractivity gradients defined by profile *htdum* and *refdum*	M-units/ meter
hfangr	Cut-back angles	radians
hlim	Array containing height at each output range separating the RO region from the PE (at close ranges) and XO (at far ranges) regions	meters
href	Heights of refractivity profile with respect to y_{ref}	meters
htdum	Height array for current interpolated profile	meters
htfe	Array containing the height at each output range separating the FE region from the RO region (full hybrid mode), or the FE region from the PE region (partial hybrid mode)	meters
i_{error}	Integer variable indicating error number for ALLOCATE and DEALLOCATE statements	N/A
igrnd	Integer array containing ground type composition for given terrain profile - can vary with range. Different ground types are: 0 = seawater 1 = freshwater 2 = wet ground 3 = medium dry ground 4 = very dry ground 5 = ice at -1 degree C 6 = ice at -10 degree C 7 = user-defined (in which case, values of relative permittivity and conductivity must be given).	N/A
nc^2	Array of complex dielectric constants	N/A
rdt	Array of minimum ranges at which diffraction field solutions are applicable (for smooth surface) for all output receiver heights.	meters
refdum	M-unit array for current interpolated profile	M-units
refref	Refractivity profile with respect to y_{ref}	M-units
rfac1	Propagation factor at valid output height points from PE field at range r_{last}.	dB
rfac2	Propagation factor at valid output height points from PE field at range *r*	dB
rgrnd	Array containing ranges at which varying ground types apply	meters
rlogo	Array used for storing 20 LOG_{10}(output ranges)	N/A
rloss	Propagation loss	dB
rngout	Array containing all desired output ranges	meters
rsqrd	Array containing the square of all desired output ranges	$meters^2$
slp	Slope of each segment of terrain	N/A
$\vartheta 0$	Array of angles used to determine common volume scattering angle	radians
$\vartheta 2s$	Array of tangent angles from all output receiver heights - used with smooth surface	radians
tx	Range points of terrain profile	meters
ty	Adjusted height points of terrain profile	meters
zout	Array containing all desired output heights referenced to h_{minter}	meters

Table 11. ALLARRAY_APM SU output data element requirements. (continued)

Name	Description	Units
zoutma	Array output heights relative to “real” ant_{ref}	meters
zoutpa	Array output heights relative to “image” ant_{ref}	meters
zxo	Height of the ground at the current output range step	meters

5.1.2 Allocate Array PE (ALLARRAY_PE) SU

The ALLARRAY_PE SU allocates and initializes all dynamically dimensioned arrays associated with PE calculations.

The ALLARRAY_PE SU utilizes the FORTRAN ALLOCATE and DEALLOCATE statements to dynamically size arrays that have been previously declared with the ALLOCATABLE attribute in the APM_MOD module or to free the array storage space previously reserved in an ALLOCATE statement. Each dimension of the ALLOCATABLE array is indicated by a colon in the APM_MOD MODULE (e.g., *array*(:)). The ALLOCATE statement establishes the upper and lower bounds of each dimension and reserves sufficient memory. Because attempting to allocate a previously allocated array causes a run-time error, each ALLOCATE statement for an array is preceded by a test to determine if it has been allocated. If it has, it is deallocated before it is allocated.

Initially, the integer used to indicate an error, i_{error}, is set to zero. If in attempting to allocate an array, a value of i_{error} other than zero is returned by an ALLOCATE statement, then the SU is exited. Note that each array that is dynamically allocated in this SU is initialized to zero.

Three integers input to this SU are used to dynamically allocate the arrays. Unless otherwise indicated, these integers are used as the single dimension of the dynamically allocated array. The first, n_{fft}, is the transform size. The second, n_4, is the transform size n_{fft} divided by four. The third, n_{zout_rtg}, is the number of receiver heights specified relative to the local surface elevation and is used to allocate the *rloss_rtg* array.

The definitions of the following arrays allocated in this SU are given in Table 13. The arrays that are allocated using the integer n_{fft} are *envpr*, *frsp*, *U*, *Ulast*, *ht*, *profint*, *udum*, *rn*, *w*, and *ym*. The only array allocated using the integer n_4 is *filt*. If rough sea surface or finite conductivity calculations are <u>not</u> required (*ruf* = ‘.false.’ and i_{pol} = 0), then arrays *rn*, *w*, and *ym* will not be allocated.

Table 12 and Table 13 provide identification, description, units of measure, and the computational source for each ALLARRAY_PE SU input and output data element.

Table 12. ALLARRAY_PE SU input data element requirements.

Name	Description	Units	Source
i_{alg}	Integer flag indicating which DMFT algorithm is being used: 0 = no DMFT algorithm will be used 1 = use central difference algorithm 2 = use backward difference algorithm	N/A	APMINIT CSC
i_{pol}	Polarization flag: 0 = horizontal polarization 1 = vertical polarization	N/A	Calling CSCI
lrtg	Logical flag indicating if loss relative to the local ground height needs to be computed. '.true.' = Compute loss relative to ground at heights specified by array *zout_rtg*. '.false.' = Do not compute loss.	N/A	APMINIT CSC
n_{fft}	Transform size	N/A	FFTPAR SU
n_4	¼ nfft	N/A	APMINIT CSC
n_{zout_rtg}	Number of output receiver heights specified relative to the local surface elevation.	N/A	Calling CSCI
ruf	Logical flag indicating if rough sea surface calculations are required '.true.' = perform rough sea surface calculations '.false.' = do not perform rough sea surface calculations	N/A	APMINIT CSC

Table 13. ALLARRAY_PE SU output data element requirements.

Name	Description	Units
envpr	Complex [refractivity] phase term array interpolated every Δz_{PE} in height	N/A
filt	Cosine-tapered (Tukey) filter array	N/A
frsp	Complex free space propagator term array	N/A
ht	PE mesh height array of size n_{fft}	meters
i_{error}	Integer variable indicating error number for ALLOCATE and DEALLOCATE statements	N/A
profint	Profile interpolated to every Δz_{PE} in height	M-units
rloss_rtg	Propagation loss computed relative to the local ground height at heights specified by *zout_rtg*	dB
rn	Array of R_T to the i^{th} power (e.g., $rn_i = R^i_T$)	N/A
U	Complex field at current PE range *r*	µV/m
Udum	Dummy array used for temporary storage of real or imaginary part of complex PE field array *U*	µV/m
Ulast	Complex field at previous PE range r_{last}	µV/m
w	Difference equation of complex PE field	µV/m
ym	Particular solution of difference equation	N/A

5.1.3 Allocate Array RO (ALLARRAY_RO) SU

The ALLARRAY_RO SU allocates and initializes all dynamically dimensioned arrays associated with RO calculations.

The ALLARRAY_RO SU utilizes the FORTRAN ALLOCATE and DEALLOCATE statements to dynamically size arrays that have been previously declared with the ALLOCATABLE attribute in the APM_MOD MODULE or to free the array storage space previously reserved in an ALLOCATE statement. Each dimension of the ALLOCATABLE array is indicated by a colon in the APM_MOD module (e.g., *array*(:)). The ALLOCATE statement establishes the upper and lower bounds of each dimension and reserves sufficient memory. Because attempting to allocate a previously allocated array causes a run time error, each ALLOCATE statement for an array is preceded by a test to determine if it has been allocated. If it has, it is deallocated before it is allocated.

Initially, the integer used to indicate an error, i_{error}, is set to zero. If in attempting to allocate an array, a value of i_{error} other than zero is returned by an ALLOCATE statement, then the SU is exited. Note that each array that is dynamically allocated in this SU is initialized to zero.

Two integers input to this SU are used to dynamically allocate the arrays. Unless otherwise indicated, these integers are used as the single dimension of the dynamically allocated array. The first of these is *lvlp*, the number of points in the refractivity profile, and the second is n_{zout}, which is the number of output height points desired.

The definitions of the following arrays allocated in this SU are given in Table 15. The array *zro* is allocated using the integer n_{zout}. The remainder of the arrays associated with refractivity information, *gr*, *q*, *rm*, and *zrt*, are allocated using the integer *lvlpt*, which is equal to *lvlp* plus one.

Table 14 and Table 15 provide identification, description, units of measure, and the computational source for each ALLARRAY_RO SU input and output data element.

Table 14. ALLARRAY_RO input data element requirements.

Name	Description	Units	Source
lvlp	Number of levels in refractivity profile	N/A	Calling CSCI
n_{zout}	Number of desired output height points	N/A	Calling CSCI

Table 15. ALLARRAY_RO output data element requirements.

Name	Description	Units
gr	Intermediate M-unit gradient array	M-units/meter
q	Intermediate M-unit difference array	M-units
rm	Intermediate M-unit array	M-units
zro	Array of output heights	meters
zrt	Intermediate height array	meters

5.1.4 Allocate Array XORUF (ALLARRAY_XORUF) SU

The ALLARRAY_XORUF SU allocates and initializes all dynamically dimensioned arrays associated with XO and rough sea surface calculations.

The ALLARRAY_XORUF SU utilizes the FORTRAN ALLOCATE and DEALLOCATE statements to dynamically size arrays that have been previously declared with the ALLOCATABLE attribute in the APM_MOD MODULE or to free the array storage space previously reserved in an ALLOCATE statement. Each dimension of the ALLOCATABLE array is indicated by a colon in the APM_MOD module (e.g., *array*(:)). The ALLOCATE statement establishes the upper and lower bounds of each dimension and reserves sufficient memory. Because attempting to allocate a previously allocated array causes a run time error, each ALLOCATE statement for an array is preceded by a test to determine if it has been allocated. If it has, it is deallocated before it is allocated.

Initially, the integer used to indicate an error, i_{error}, is set to zero. If in attempting to allocate an array, a value of i_{error} other than zero is returned by an ALLOCATE statement, then the SU is exited. Note that each array that is dynamically allocated in this SU is initialized to zero.

Six integers input to this SU are used to dynamically allocate the arrays. Unless otherwise indicated, these integers are used as the single dimension of the dynamically allocated array. The first of these is i_{xo} and is the number of XO range step calculations required. The second is iz_{max}, the maximum number of points allocated for arrays associated with XO calculations. The third is *lvlp*, the number of points in the refractivity profile. The fourth is n_{p4}, 1/4 of the number of points, n_p, used in the top or bottom portion of the PE region for spectral estimation. The fifth is n_{rout}, the number of output range points desired, and the last is n_s, the transform size used in spectral estimation calculations (i.e., $n_s=2^{ln_p}$), where the integer ln_p is the power of 2 transform size.

The definitions of the following arrays allocated in this SU are given in Table 17. The array *ffrout* is allocated using the integer n_{rout} as the first dimension and two as the second dimension. The integer iz_{max} is used as the first dimension limit, and the integer three is used as the second dimension in the allocation of the array *ffacz*. Both of the

arrays, *grad* and *htr* are allocated with the first dimension given by *lvlp* and the second dimension given by iz_{max}. The array *lvl* is allocated using the integer iz_{max}. The array *filtp* is allocated using the integer n_{p4}. The three arrays *xp*, *yp*, and *spectr* are allocated using the integer n_s.

If no XO calculations are required (i_{xo} = 0) then the arrays *ffrout, ffacz, grad, htr*, and *lvl* will not be allocated.

Table 16 and 17 provide identification, description units of measure, and the computational source for each ALLARRAY_XORUF SU input and output data element.

Table 16. ALLARRAY_XORUF SU input data element requirements.

Name	Description	Units	Source
i_{xo}	Number of range steps in XO calculation region	N/A	APMINIT CSC
iz_{max}	Maximum number of points allocated for arrays associated with XO calculations	N/A	APMINIT CSC
lvlp	Number of height/refractivity levels in profiles	N/A	Calling CSCI
n_{p4}	¼ n_p	N/A	APMINIT CSC
n_{rout}	Integer number of output range points desired	N/A	Calling CSCI
n_s	Transform size for spectral estimation calculations	N/A	APMINIT CSC

Table 17. ALLARRAY_XORUF SU output data element requirements.

Name	Description	Units
ffacz	Two-dimensional array containing propagation factor, range, and outgoing propagation angle at z_{lim}	dB, meters, radians
ffrout	Two-dimensional array of propagation factors at each output range beyond r_{atz} and at height z_{lim}	dB
filtp	Array filter for spectral estimation calculations	N/A
grad	Two-dimensional array containing gradients of each profile used in XO calculations	M-units/ meter
htr	Two-dimensional array containing heights of each profile used in XO calculations	meters
i_{error}	Integer variable indicating error number for ALLOCATE and DEALLOCATE statements	N/A
lvl	Number of height levels in each profile used in XO calculations	N/A
spectr	Spectral amplitude of field	dB
xp	Real part of spectral portion of PE field	μV/m
yp	Imaginary part of spectral portion field	μV/m

5.1.5 Alpha Impedance Initialization (ALN_INIT) SU

The ALN_INIT SU initializes variables and arrays used for the backward or central difference form of the DMFT algorithm. The DMFT algorithm is used only for finite conductivity and/or rough sea surface calculations.

Upon entering, the GETALN SU is referenced to obtain the surface impedance, α_s, the complex root R_T, the array *rn* containing the powers of the complex root, and a coefficient R_k used in the central difference algorithm. These variables are computed from the grazing angle ψ and current range, which, for initialization purposes are set equal to $\pi/2$ and 0, respectively.

If the central difference algorithm is required (i_{alg}=1) for the particular APM CSCI application, then coefficients necessary for this form of the DMFT are computed as follows:

$$ck_1 = R_k \left[.5\left(U_0 + U_{n_{fft}}\, rn_{n_{fft}}\right) + \sum_{i=1}^{n_{m1}} U_i\, rn_i \right]$$

$$ck_2 = R_k \left[.5\left(U_0\, rn_{n_{fft}} + U_{n_{fft}}\right) + \sum_{i=1}^{n_{m1}} (-1)^i U_{n_{fft}-i}\, rn_i \right]$$

If the backward difference algorithm is required (i_{alg}=2) for the particular APM CSCI application, then the variable *cmft* is initialized using the starting PE field *U* and the array *rn* according to

$$cmft = \sum_{i=1}^{n_{m1}} U_i rn_i \ .$$

Table 18 and Table 19 provide identification, description, units of measure, and the computational source for each ALN_INIT SU input and output data element.

Table 18. ALN_INIT SU input data element requirements.

Name	Description	Units	Source
ψ	Grazing angle	radians	APMINIT CSC
i_{alg}	Integer flag indicating which DMFT algorithm is being used: 0 = no DMFT algorithm will be used 1 = use central difference algorithm 2 = use backward difference algorithm	N/A	APMINIT CSC
r	Current range	meters	APMINIT CSC
n_{m1}	n_{fft} -1	N/A	APMINIT CSC

Table 18. ALN_INIT SU input data element requirements. (continued)

Name	Description	Units	Source
R_k	Constant used to compute coefficients in central difference form of the DMFT	N/A	GETALN SU
rn	Array of R_T to the i^{th} power (e.g., $rn_i = R_T^i$)	N/A	GETALN SU
U	Complex field at current PE range r	μV/m	XYINIT SU

Table 19. ALN_INIT SU output data element requirements.

Name	Description	Units
ck_1	Coefficient used in central difference form of DMFT	N/A
ck_2	Coefficient used in central difference form of DMFT	N/A
$cmft$	Coefficient used in backward difference form of DMFT	N/A

5.1.6 Antenna Pattern (ANTPAT) SU

The ANTPAT SU calculates an antenna pattern factor (normalized antenna gain), $f(\alpha)$, for a specified antenna elevation angle, α. Currently, antenna pattern factors are included for seven types of antennas. These patterns include an omnidirectional (i_{pat}=1) type; a Gaussian ($i_{pa\ t}$= 2) type; a Sin(X)/X (i_{pat}=3) type; a cosecant-squared (i_{pat} = 4) type; a generic height-finder ($i_{pa\ t}$ = 5) type; a user-defined height-finder type (i_{pat} = 6), in which the calling CSCI must also specify an array of cut-back angles and pattern factors; a user-defined antenna type (i_{pat} = 7), in which the calling CSCI must specify an array of antenna pattern factors and angles; and finally, a quarter-wave dipole antenna type (i_{pat} =8), suitable for HF applications.

From two antenna pattern quantities determined in the APMINIT CSC, ant_{fac} and p_{elev}; the antenna beam width, μ_{bwr}, and elevation angle, μ_{or}; a specified angle, α, for which the antenna pattern factor is desired; and the antenna radiation pattern type, i_{pat}, the antenna pattern factor is calculated as follows.

If the antenna pattern is omnidirectional, then $f(\alpha) = 1$. If the antenna pattern is Gaussian, then

$$f(\alpha) = e^{-ant_{fac}\left[\mathbf{SIN}(\alpha) - p_{elev}\right]^2} .$$

If the antenna pattern is cosecant-squared, compute the elevation angle relative to the antenna elevation angle as

$$\alpha_{pat} = \alpha - \mu_{or} .$$

The antenna pattern is now given as

$$f(\alpha)=\frac{\mathbf{SIN}(\mu_{bwr})}{\mathbf{SIN}(\alpha_{pat})}\ , \qquad \text{for } \alpha_{pat} > \mu_{bwr}\ ,$$

$$f(\alpha)=\mathbf{MAX}\left(0.0\mathbf{,}\left[1+\frac{\alpha_{pat}}{\mu_{bwr}}\right]\right), \qquad \text{for } \alpha_{pat} < 0,$$

$$f(\alpha)=1 \quad \text{otherwise.}$$

If the antenna pattern is Sin(X)/X, a generic height-finder, or a user-specified height-finder, the following calculations are made:

1. The elevation angle relative to the antenna elevation angle, α_{pat}, is determined as in the previous definition. If the antenna radiation pattern type is a generic or user-specified height-finder, the radiation pattern is simulated as a Sin(X)/X type with the elevation angle adjusted to account for the current pointing angle of the main beam, χ. χ is set equal to the antenna elevation angle μ_{or}. If the direct-path ray angle, α_d, is greater than the antenna elevation angle, then α_{pat} is computed as $\alpha_{pat} = \alpha - \alpha_d$ and χ is set equal to α_d.

2. The antenna pattern is now given as

$$f(\alpha)=1 \qquad \text{for } \left|\alpha_{pat}\right| \le 10^{-6}$$

$$f(\alpha)=\frac{\mathbf{SIN}\left[ant_{fac}\ \mathbf{SIN}(\alpha_{pat})\right]}{ant_{fac}\ \mathbf{SIN}(\alpha_{pat})}; \qquad \text{for } \left|\alpha_{pat}\right| < \mu_{max},$$

$$f(\alpha)= side_{lim}\text{, otherwise,}$$

where $side_{lim}$ is 0.03 for a Sin(x)/x antenna pattern, and 0.0 otherwise.

For a user-defined height-finder, the pattern factor is further adjusted by a power reduction factor, $hffac_i$, as

$$f(\alpha)= f(\alpha)\ hffac_i \qquad i = n_{facs}, \ldots 2, 1$$

where i is an angle counter, decremented by one from the number of power reduction angles, n_{facs} , for each power reduction angle, $hfangr_i$, which exceeds χ.

For the user-defined antenna type, the antenna pattern factor is simply the array *hffac* provided by the calling CSCI at angles *hfangr*, where pattern factors are interpolated from *hffac* for angles α within *hfangr*.

Finally, for the quarter-wave dipole antenna pattern, the antenna pattern factor is defined as

$$s_\alpha = \mathbf{SIN}(|\alpha|), c_\alpha = \mathbf{COS}(|\alpha|)$$
$$s_r = nc_1^{2^*} s_\alpha \,, c_r = \sqrt{nc_1^{2^*} - c_\alpha^2} \;;$$

$$\Gamma_n = s_r - c_r \,, \Gamma_d = s_r + c_r$$
$$t_4 = \mathbf{TAN}^{-1} \frac{\Im(\Gamma_n)}{\Re(\Gamma_n)}, t_5 = \mathbf{TAN}^{-1} \frac{\Im(\Gamma_d)}{\Re(\Gamma_d)}$$

$$\Gamma = \frac{|\Gamma_n|}{|\Gamma_d|}, \;\; e_o = \mathbf{COS}(\tfrac{\pi}{2} s_\alpha), \;\; t_9 = t_4 - t_5 + \pi s_\alpha$$
$$E_r = e_o - e_o \Gamma\, \mathbf{COS}(t_9) \,,\; E_j = e_o \Gamma\, \mathbf{SIN}(t_9)$$
$$f(\alpha) = \tfrac{1}{2}\sqrt{E_r^{\,2} + E_j^{\,2}}$$

Table 20 and Table 21 provide identification, description, units of measure, and the computational source for each ANTPAT SU input and output data element.

Table 20. ANTPAT SU input data element requirements.

Name	Description	Units	Source
ant_{fac}	Antenna pattern parameter (depends on i_{pat} and μ_{bwr})	N/A	APMINIT CSC
α	Antenna elevation angle	radians	Calling SU
α_d	Direct ray elevation angle	radians	FEDR SU FEM SU ROCALC SU TROPOINIT SU TROPOSCAT SU XYINIT SU

Table 20. ANTPAT SU input data element requirements. (continued)

Name	Description	Units	Source
$hfangr$	Cut-back angles if i_{pat} = 6; Antenna pattern angles if i_{pat} = 7	radians	Calling CSCI
$hffac$	Cut-back antenna pattern factors if i_{pat} = 6; Antenna pattern factors if i_{pat} = 7	N/A	Calling CSCI
i_{pat}	Antenna pattern type 1 = Omnidirectional 2 = Gaussian 3 = Sine(x)/x 4 = Cosecant-squared 5 = Generic height-finder 6 = User-defined height-finder 7 = User-defined antenna pattern	N/A	Calling CSCI
μ_{or}	Antenna pattern (pointing) elevation angle	radians	APMINIT CSC
μ_{bwr}	Antenna vertical beam width	radians	APMINIT CSC
μ_{max}	Limiting angle for Sin(X)/X and generic height finder antenna pattern factors	radians	APMINIT CSC
nc^2	Array of complex dielectric constants	N/A	DIEINIT SU
n_{facs}	Number of user-defined cut-back angles and cut-back pattern factors	N/A	Calling CSCI
p_{elev}	Sine of antenna elevation angle	N/A	APMINIT CSC

Table 21. ANTPAT SU output data element requirements.

Name	Description	Units
$f(\alpha)$	Antenna pattern factor for elevation angle α	N/A

5.1.7 APM Status (APMSTATUS) SU

This SU is supplied with the APM CSCI and should be declared as an external subroutine. It is called from the GETANGLES SU as a means of checking the status of the algorithm for computing grazing angles, as this can be time-intensive before the actual propagation loss calculations are performed.

5.1.8 Dielectric Initialization (DIEINIT) SU

The DIEINIT SU determines the conductivity and relative permittivity as a function of frequency in megahertz, based on general ground composition types.

The DIEINIT SU supports the following general ground types: salt water, fresh-water, wet ground, medium dry ground, very dry ground, ice at -1 °C, ice at -10 °C, and user-defined. For all ground types other than “user-defined,” the permittivity and

conductivity are calculated as functions of frequency from curve fits to the permittivity and conductivity graphs shown in the Recommendations and Reports of the International Radio Consultative Committee (CCIR, 1986). For the i^{th} input ground type case, $igrnd_i$, the permittivity ε_r and conductivity σ are determined as follows:

For salt water ($igrnd_i$ = 0), the relative permittivity is given by 70 for $f_{MHz} \leq 2253.5895$; and the conductivity is given by 5.0 S/m for $f_{MHz} \leq 1106.207$. For $f_{MHz} > 2253.5895$, the relative permittivity is given by

$$\varepsilon_r = \begin{bmatrix} 1.4114535 \times 10^{-2} - 5.2122497 \times 10^{-8} f_{MHz} + 5.8547829 \times 10^{-11} f_{MHz}^2 \\ - 7.6717423 \times 10^{-16} f_{MHz}^3 + 2.9856318 \times 10^{-21} f_{MHz}^4 \end{bmatrix}^{-1} .$$

For $f_{MHz} > 1106.207$, the conductivity σ in S/m is given by

$$\sigma = \frac{3.8586749 + 9.1253873 \times 10^{-4} f_{MHz} + 1.530992 \times 10^{-8} f_{MHz}^2}{1. - 2.1179295 \times 10^{-5} f_{MHz} + 6.5727504 \times 10^{-10} f_{MHz}^2 - 1.9647664 \times 10^{-15} f_{MHz}^3} .$$

For freshwater ($igrnd_i$ = 1), the relative permittivity ε_r is given by 80 for $f_{MHz} \leq 6165.776$. For higher frequencies, ε_r is given by

$$\varepsilon_r = \frac{79.027635 - 3.5486605 \times 10^{-4} f_{MHz} + 8.210184 \times 10^{-9} f_{MHz}^2}{1. - 2.2083308 \times 10^{-5} f_{MHz} + 2.7067836 \times 10^{-9} f_{MHz}^2 - 1.0007669 \times 10^{-14} f_{MHz}^3} .$$

For $f_{MHZ} > 5776.157$, the conductivity σ in S/m is given by

$$\sigma = \left(\frac{-.65750351 + 6.6113198 \times 10^{-4} f_{MHz} + 1.4876952 \times 10^{-9} f_{MHz}^2}{1. + 5.5620223 \times 10^{-5} f_{MHz} + 3.0140816 \times 10^{-10} f_{MHz}^2} \right)^2 .$$

For $f_{MHZ} \leq 5776.157$, the conductivity σ in S/m is given by

$$\sigma = \left(\frac{201.97103 + 1.2197967 \times 10^{-2} f_{MHz} - 1.728776 \times 10^{-6} f_{MHz}^2}{1. - 2.5539582 \times 10^{-3} f_{MHz} - 3.7853169 \times 10^{5} f_{MHz}^2} \right)^{-1} .$$

For wet ground ($igrnd_i$ = 2), the relative permittivity ε_r is given by 30 for $f_{MHz} \le 1312.054$. For $1312.054 < f_{MHz} < 4228.11$, the relative permittivity ε_r is given by

$$\varepsilon_r = \sqrt{\frac{857.94335 + 5.5275278 \times 10^{-2} f_{MHz}}{1. - 8.9983662 \times 10^{-5} f_{MHz} + 8.8247139 \times 10^{-8} f_{MHz}^2}} \ .$$

For $f_{MHz} \ge 4228.11$, the relative permittivity ε_r is given by

$$\varepsilon_r = \sqrt{\frac{915.31026 - 4.0348211 \times 10^{-3} f_{MHz} + 7.4342897 \times 10^{-7} f_{MHz}^2}{1. - 9.4530022 \times 10^{-6} f_{MHz} + 4.892281 \times 10^{-8} f_{MHz}^2}} \ .$$

For $f_{MHz} > 15454.4$, the conductivity σ in S/m for wet ground is given by

$$\begin{aligned}\sigma &= 0.8756665 + 4.7236085 \times 10^{-5} f_{MHz} + 2.6051966 \times 10^{-8} f_{MHz}^2 \\ &- 9.235936 \times 10^{-13} f_{MHz}^3 + 1.4560078 \times 10^{-17} f_{MHz}^4 \\ &- 1.1129348 \times 10^{-22} f_{MHz}^5 + 3.3253339 \times 10^{-28} f_{MHz}^6 .\end{aligned}$$

For $f_{MHz} \le 15454.4$, the conductivity σ in S/m for wet ground is given by

$$\begin{aligned}\sigma &= 5.5990969 \times 10^{-3} + 8.7798277 \times 10^{-5} f_{MHz} + 6.2451017 \times 10^{-8} f_{MHz}^2 \\ &- 7.1317207 \times 10^{-12} f_{MHz}^3 + 4.2515914 \times 10^{-16} f_{MHz}^4 \\ &- 1.240806 \times 10^{-20} f_{MHz}^5 + 1.3854354 \times 10^{-25} f_{MHz}^6 .\end{aligned}$$

For medium dry ground ($igrnd_i$ = 3), the relative permittivity ε_r is given by 15 for $f_{MHz} \le 4841.945$. For $f_{MHz} > 4841.945$, the relative permittivity ε_r is given by

$$\varepsilon_r = \sqrt{\frac{215.87521 - 2.6151055 \times 10^{-3} f_{MHz} + 1.9484482 \times 10^{-7} f_{MHz}^2}{1. - 7.6649237 \times 10^{-5} f_{MHz} + 1.2565999 \times 10^{-8} f_{MHz}^2}} \ .$$

At $f_{MHz} \le 4946.751$ for medium dry ground, the conductivity σ in S/m is given by

$$\begin{aligned}\sigma &= (2.4625032 \times 10^{-2} + 1.8254018 \times 10^{-4} f_{MHz} - 2.664754 \times 10^{-8} f_{MHz}^2 \\ &+ 7.6508732 \times 10^{-12} f_{MHz}^3 - 7.4193268 \times 10^{-16} f_{MHz}^4)^2 .\end{aligned}$$

For $f_{MHz} > 4946.751$, for medium dry ground, the conductivity σ in S/m is given by

$$\sigma = (0.17381269 + 1.2655183 \times 10^{-4} f_{MHz} - 1.6790756 \times 10^{-9} f_{MHz}^{2} + 1.1037608 \times 10^{-14} f_{MHz}^{3} - 2.9223433 \times 10^{-20} f_{MHz}^{4})^{2}.$$

For very dry ground (*igrnd*$_i$ = 4), the relative permittivity ε_r is given by 3 and the conductivity σ in S/m is 0.0001 for $f_{MHz} < 590.8924$. For $590.8924 \le f_{MHz} \le 7131.933$, the conductivity σ in S/m is given by

$$\begin{aligned}\sigma = {} & 2.2953743 \times 10^{-4} - 8.1212741 \times 10^{-7} f_{MHz} + 1.8045461 \times 10^{-9} f_{MHz}^{2} \\ & - 1.960677 \times 10^{-12} f_{MHz}^{3} + 1.256959 \times 10^{-15} f_{MHz}^{4} - 4.46811 \times 10^{-19} f_{MHz}^{5} \\ & + 9.4623158 \times 10^{-23} f_{MHz}^{6} - 1.1787443 \times 10^{-26} f_{MHz}^{7} + 7.9254217 \times 10^{-31} f_{MHz}^{8} \\ & - 2.2088286 \times 10^{-35} f_{MHz}^{9}.\end{aligned}$$

For $f_{MHz} > 7131.933$ MHz, the conductivity σ in S/m is given by

$$\sigma = (-4.9560275 \times 10^{-2} + 2.9876572 \times 10^{-5} f_{MHz} - 3.0561848 \times 10^{-10} f_{MHz}^{2} + 1.1131828 \times 10^{-15} f_{MHz}^{3})^{2}.$$

For ice at -1°C (*igrnd*$_i$ = 5), the relative permittivity ε_r is 3 for all frequencies, and the conductivity σ, for $f_{MHz} \le 300$, is given by

$$\sigma = \frac{3.8814567 \times 10^{-5} + 9.878241 \times 10^{-6} f_{MHz} + 7.9902484 \times 10^{-8} f_{MHz}^{2}}{1 + 8.467523 \times 10^{-2} f_{MHz} - 9.736703 \times 10^{-5} f_{MHz}^{2} + 3.269059 \times 10^{-7} f_{MHz}^{3}},$$

and for $f_{MHz} > 300$ is given by

$$\sigma = \frac{1.2434792 \times 10^{-4} + 8.680839 \times 10^{-7} f_{MHz} + 7.2701689 \times 10^{-11} f_{MHz}^{2} - 2.6416983 \times 10^{-14} f_{MHz}^{3} + 1.37552 \times 10^{-18} f_{MHz}^{4}}{1 + 2.824598 \times 10^{-4} f_{MHz} - 6.755389 \times 10^{-8} f_{MHz}^{2} + 2.8728975 \times 10^{-12} f_{MHz}^{3} - 1.8795958 \times 10^{-18} f_{MHz}^{4}}.$$

For ice at -10° C (*igrnd*$_i$ = 6), the relative permittivity ε_r is 3 for all frequencies, and the conductivity σ, for $f_{MHz} \le 8753.398$, is given by

$$\sigma = \frac{1 + 3.883854 \times 10^{-2} f_{MHz} + 6.832108 \times 10^{-5} f_{MHz}^{2}}{51852.543 + 389.58894 f_{MHz}},$$

and for $f_{MHz} > 8753.398$, is given by

$$\sigma = 4.13105 \times 10^{-5} + 2.03589 \times 10^{-7} f_{MHz} - 3.1739 \times 10^{-12} f_{MHz}^2 + 4.52331 \times 10^{-17} f_{MHz}^3 .$$

For the user-defined ground type (*igrnd*$_i$ = 7), the relative permittivity ε_r and the conductivity σ in S/m are set equal to the input values $dielec_{1,i}$ and $dielec_{2,i}$, respectively.

Finally, the complex dielectric constant is given by

$$nc_i^2 = \varepsilon_{ri} + 60\lambda\sigma_i; \quad for \;\; i = 1,2,3,\ldots i_{gr} .$$

Table 22 and Table 23 provide identification, description, units of measure, and the computational source for each DIEINIT SU input and output data element.

Table 22. DIEINIT SU input data element requirements.

Name	Description	Units	Source
dielec	Two-dimensional array containing the relative permittivity and conductivity; $dielec_{1,i}$ and $dielec_{2,i}$, respectively.	N/A, S/m	Calling CSCI
f_{MHz}	Frequency	MHz	APM_MOD
i_{gr}	Number of different ground types specified	N/A	Calling CSCI
igrnd	Integer array containing ground type composition for given terrain profile - can vary with range. Different ground types are: 0 = seawater 1 = freshwater 2 = wet ground 3 = medium dry ground 4 = very dry ground 5 = ice at -1 degree C 6 = ice at -10 degree C 7 = user-defined (in which case, values of relative permittivity and conductivity must be given).	N/A	Calling CSCI
λ	Wavelength	meters	APMINIT CSC
rgrnd	Array containing ranges at which varying ground types apply.	meters	Calling CSCI

Table 23. DIEINIT SU output data element requirements.

Name	Description	Units
nc^2	Array of complex dielectric constants	N/A

5.1.9 FFT Parameters (FFTPAR) SU

The FFTPAR SU determines the required transform size based on the maximum PE propagation angle and the maximum height needed for desired coverage. If running in full or partial hybrid modes, the maximum height is the height necessary to encompass at least 20% above the maximum terrain peak along the path or the highest trapping layer specified in the environment profiles, whichever is greater. If running in a PE-only mode, the maximum height is the specified maximum output height.

For computational efficiency reasons, an artificial upper boundary is established for the PE solution. To prevent upward propagating energy from being "reflected" downward from this boundary and contaminating the PE solution, the PE solution field strength is attenuated or "filtered" above a certain height to ensure that the field strength just above this boundary is reduced to zero. The bin width in z-space Δz_{PE} is found from

$$\Delta z_{PE} = \frac{\lambda}{2\,\mathbf{SIN}(\Theta_{max})},$$

where λ is the wavelength in meters and Θ_{max} is the maximum propagation angle in radians.

The flag, i_{flag}, is used to determine maximum FFT size based on a given Θ_{max} and desired coverage height z_{lim} or it will determine z_{lim} based on a given Θ_{max} and FFT size.

For $i_{fla\ g}$= 0, the constants ln_{fft}, n_{fft}, and z_{max} are found from ln_{min} as follows,

$$ln_{fft} = ln_{min},$$
$$n_{fft} = 2^{ln_{fft}},$$
$$z_{max} = n_{fft}\Delta z_{PE},$$

where ln_{min} is the minimum power of two transform size. ln_{min} is initialized to 10 and for every 5° in Θ_{max} is increased by 1. Next, the transform size needed to perform calculations to a test height z_t is determined. First, z_t is set equal to z_{lim} minus a small height precision tolerance. Then a DO WHILE loop is executed as long as the condition ¾ $z_{max} < z_t$ is satisfied. Within this DO WHILE loop z_{max} is found from

$$ln_{fft} = ln_{fft} + 1,$$
$$n_{fft} = 2^{ln_{fft}},$$
$$z_{maz} = n_{fft}\Delta z_{PE}.$$

If ln_{fft} reaches the value of 30, then the SU is exited with a non-zero error code.

For the case where i_{flag} = 1, no iteration needs to be performed. z_{lim} is determined by a given ln_{fft} and Θ_{max} from equations shown above.

Upon exiting, z_{lim} is computed as ¾ z_{max}.

Table 24 and Table 25 provide identification, description, units of measure, and the computational source for each FFTPAR SU input and output data element.

Table 24. FFTPAR SU input data element requirements.

Name	Description	Units	Source
i_{flag}	Flag indicating whether to determine maximum FFT size n_{fft} based on given Θ_{max} and z_{lim} or determine z_{lim} based on given Θ_{max} and FFT size n_{fft}.	N/A	APMINIT CSC GETTHMAX SU
λ	Wavelength	meters	APMINIT SU
ln_{min}	Minimum power of 2 transform size	N/A	APMINIT SU
Θ_{max}	Maximum propagation angle in PE calculations	radians	APMINIT CSC GETTHMAX SU
z_{lim}	Maximum height region where PE solution is valid	meters	APMINIT CSC GETTHMAX SU

Table 25. FFTPAR SU output data element requirements.

Name	Description	Units
Δz_{PE}	Bin width in z space	meters
i_{err}	Error code	N/A
ln_{fft}	Power of 2 transform size, i.e. n_{fft}=2 ln_{fft}	N/A
n_{fft}	Transform size	N/A
z_{lim}	Maximum height region where PE solution is valid	meters
z_{max}	Total height of the FFT/PE calculation domain	meters

5.1.10 Fill Height Arrays (FILLHT) SU

The FILLHT SU calculates the effective earth radius for an initial launch angle of 5° and to fill an array with height values at each output range of the limiting sub-model, depending on which mode is used. If running in a full hybrid mode, the array contains height values at each output range, separating the PE from the RO region. If running in partial hybrid or PE-only modes, the array contains those height values at each output range at which the initial launch angle has been traced to the ground or surface. These height values represent the separating region where, above that height, valid loss is computed, and below that height, no loss is computed so that only loss values that fall within a valid calculation region are output.

For the case when i_{hybrid} = 1 (full hybrid mode), all height values at each output range separating the FE region from the RO region are determined and stored in array *htfe*. For ranges greater than 2.5 km, the ray defined by a 5° elevation angle is traced up to the maximum height ht_{lim}. The ray is "traced" by simple geometry at every output range and the height array *htfe* is determined as follows. The temporary variable y_{ar} is found from

$$y_{ar} = y_{fref} - ant_{ref},$$

where the parameter y_{fref} is the ground elevation height at the source, and ant_{ref} is the transmitting antenna height relative to the height h_{minter}. The values of $htfe_i$ are then determined by

$$\left.\begin{array}{l} htfe_i = y_{fref}\,\textbf{;} \quad \text{for } rngout_i \le r_{tst} \\ htfe_i = \textbf{MIN}\left(ht_{lim}\textbf{, MAX}\left\{y_{fref}\textbf{,} y_{ar} + t_5 rngout_i\right\}\right)\textbf{;} \quad \text{for } rngout_i > r_{tst} \end{array}\right\}, \; i = 1, 2, \ldots n_{rout},$$

where r_{tst} is a constant range of 2.5 km, t_5 is the tangent of 5°, and $rngout_i$ is the output range at every i^{th} range step.

For the airborne hybrid model (i_{hybrid}=0), the TRACE_ROUT SU is referenced to determine the heights at every output range separating the upper FE region from the PE region. These heights are stored in array *hlim*. The heights separating the lower FE region from the PE region are stored in array *htfe* as outlined below.

For partial hybrid (PE plus XO) or airborne modes, the initial launch angle is traced until it hits the surface, storing heights traced at each output range.

First, several variables are initialized. The angle at the start of the trace, a_0, is set to $-a_{launch}$ (determined in the GETTHMAX SU); the initial range, r_0, is set equal to zero; and the height at the start of the ray trace step, h_0, is set equal to ant_{ref}. The index, l, indicating the location of the source height in array *htdum*, is set equal to the index i_{start1}. The terrain elevation at the current range, ty_r, is initialized to 0, and the index j is set equal to one.

The following steps (1 through 2) are performed until the ray has reached the surface or the ray has been traced to r_{max}, whichever comes first.

1. The output range to trace to r_o is initialized to $rngout_j$, and $htfe_j$ is initialized to 0.

2. The TRACE_STEP SU is accessed to trace the ray to the next range step, which is incremented by Δr_{PE}. The height at that range is then stored in array *htfe*. The index *j* is incremented by one, and if the ray has not reached the surface or r_{max}, then steps 1 and 2 are repeated.

Once the ray trace is completed, the index *j* is decremented by one and $htfe_j$ is set equal to hm_{ref} for all remaining output range steps *j* through n_{rout}.

Table 26 and Table 27 provide identification, description, units of measure, and the computational source for each FILLHT SU input and output data element.

Table 26. FILLHT SU input data element requirements.

Name	Description	Units	Source
a_{launch}	Launch angle used which, when traced, separates the PE and XO regions from the RO region	radians	GETTHMAX SU
ant_{ref}	Transmitting antenna height relative to the reference height h_{minter}	meters	TERINIT SU
Δr_{PE}	PE range step	meters	PEINIT SU
f_{ter}	Logical flag indicating if terrain profile has been specified: '.true.' = terrain profile specified '.false.' = terrain profile not specified	N/A	APMINIT CSC
grdum	M-unit gradient array	(M-unit/ meter)	REFINIT SU
hmref	Height relative to h_{minter}	meters	TERINIT SU
htdum	Height array for current interpolated profile	meters	REFINIT SU
ht_{lim}	User-supplied maximum height relative to h_{minter}, i.e., $ht_{lim} = h_{max} - h_{minter}$	meters	TERINIT SU
i_{hybrid}	Integer indicating which sub-models will be used: 0 = (FEDR + PE) model 1 = full hybrid model (PE + FE + RO + XO) 2 = partial hybrid model (PE + XO)	N/A	APMINIT CSC
i_{start1}	Refractivity level index within *htdum* at ant_{ref}	N/A	REFINIT SU
lvlep	Number of refractivity levels in profile *htdum*, *refdum*	N/A	REFINIT SU
n_{rout}	Integer number of the output range points desired	N/A	Calling CSCI
rngout	Array containing all output ranges	meters	APMINIT CSC
r_{tst}	Range set at 2.5 km to begin calculation of RO values	meters	APM_MOD
Θ_{75}	75% of maximum propagation angle in PE calculations	radians	APMINIT CSC
tx	Range points of terrain profile	meters	TERINIT SU
y_{fref}	Ground elevation height at the source	meters	APMINIT CSC

Table 27. FILLHT SU output data element requirements.

Name	Description	Units
hlim	Array containing the height at each output range separating the RO region from the PE (at close ranges) and XO (at far ranges) regions	meters
htfe	Array of height values at each output range separating the PE region from the RO region	meters

5.1.11 Gaseous Absorption (GASABS) SU

The GASABS SU computes the specific attenuation based on air temperature and absolute humidity. This SU is based on CCIR (International Telecommunication Union, International Radio Consultative Committee, now the ITU-R) Recommendation 676-1, “Attenuation by Atmospheric Gases in the Frequency Range 1-350 GHz.”

The oxygen absorption for 15°C air temperature is computed from

$$\gamma_o = 10^{-3}\left(t_1 + t_2 + 0.00719\right)\left(\frac{f_{MHz}}{1000.}\right)^2,$$

where f_{MHz} is the frequency in MHz and the temporary variables t_1 and t_2 are given by

$$t_1 = \frac{6.09}{\left(\frac{f_{MHz}}{1000.}\right)^2 + 0.227},$$

$$t_2 = \frac{4.81}{\left(\frac{f_{MHz}}{1000.} - 57.0\right)^2 + 1.50}.$$

A correction is made for the oxygen absorption for the actual air temperature, which is given by

$$\gamma_o = \left(1.0 + 0.01\left\{t_{air} - 15.0\right\}\right)\gamma_o,$$

where t_{air} is the surface air temperature in degrees Centigrade.

The water vapor absorption is computed from

$$\gamma_w = \frac{\left(0.05 + 0.0021\, abs_{hum} + t_1 + t_2 + t_3\right)\left(\frac{f_{MHz}}{1000.}\right)^2 abs_{hum}}{10000.0},$$

where the temporary variables t_1, t_2, and t_3 are given respectively by

$$t_1 = \frac{3.6}{\left(\frac{f_{MHz}}{1000.} - 22.2\right)^2 + 8.5},$$

$$t_2 = \frac{10.6}{\left(\frac{f_{MHz}}{1000.} - 183.3\right)^2 + 9.0},$$

and

$$t_3 = \frac{8.9}{\left(\frac{f_{MHz}}{1000.} - 325.4\right)^2 + 26.3}.$$

The total specific absorption for sea-level air in dB/km multiplied by a conversion factor to convert to dB/m is given by

$$gas_{att} = \left(\gamma_o + \gamma_w\right)10^{-3}.$$

Table 28 and Table 29 provide identification, description, units of measure, and the computational source for each GASABS SU input and output data element.

Table 28. GASABS SU input data element requirements.

Name	**Description**	**Units**	**Source**
abs_{hum}	Absolute humidity near the surface	g/meter^3	Calling CSCI
f_{MHz}	Frequency	MHz	Calling CSCI
t_{air}	Air temperature near the surface	°C	Calling CSCI

Table 29. GASABS SU output data requirements.

Name	Description	Units
gas_{att}	Gaseous absorption	dB/m

5.1.12 Get Effective Earth Radius Factor (GET_K) SU

The GET_K SU computes the effective earth radius factor and the effective earth radius. The computation is made for a launch angle of 5° if the SU is called from the APMINIT CSC. If called from the TROPOINIT SU, then the computation is made for a launch angle equal to the critical angle.

Upon entering the SU, internal one-line ray trace functions are defined as

$$\mathbf{RADA1}(a, b) = a^2 + 2 g_{rd} b,$$
$$\mathbf{RP}(a, b) = a + \frac{b}{g_{rd}},$$

for general parameters a, b, and refractivity gradient g_{rd}.

The starting launch angle a_{start} for tracing a ray to determine the effective earth radius is initialized to the critical angle a_{crit}.

If the SU is called from the APMINIT CSC (i_{org} = 0), then a_{start} is re-initialized to 5°. If running the airborne model then the beamwidth and antenna elevation angle are taken into account and the starting angle is initialized according to

$$a_{start} = \mathbf{MIN}\left[\mathbf{MAX}\left(a_{start}, \mu_{bwr} + \mu_{lim}\right), 10^\circ\right],$$

where

$$\mu_{lim} = \mathbf{MIN}\left(10^\circ, \left|\mu_{or}\right|\right).$$

If a terrain profile has been specified (f_{ter} = '.true.'), then a_{start} is set equal to

$$a_{start} = \mathbf{MIN}\left(1.5 a_{start}, 10^\circ\right).$$

If using the airborne or full hybrid modes, or if calling from the TROPOINIT SU, then perform steps 1 through 4 to compute the effective earth radius from the antenna height up to height ht_{lim}.

1. The propagation angle, range, and height at the start of the ray trace step are initialized to a_{start}, 0., and ant_{ref}, respectively. The current refractivity level i is also initialized to i_{start1}.

2. Steps 2a through 2c are performed for an upward ray until it has reached the last height in the refractivity level or ht_{lim}, whichever comes first.

   a. The gradient g_{rd} is set equal to $grdum_i$. The propagation angle a_1 and range r_1 at the end of the trace step are computed as

$$a_1 = \sqrt{\mathbf{RADA1}\left(a_0, htdum_{i+1} - h_0\right)},$$
$$r_1 = \mathbf{RP}\left(r_0, a_1 - a_0\right).$$

   b. a_0, r_0, and h_0 are now set equal to the values of a_1, r_1 and $htdum_{i+1}$, respectively. If h_0 is greater than ht_{lim}, then the integer flag i_{flag} is set equal to 1, and the propagation angle a_1 at ht_{lim} is computed as

$$a_1 = \sqrt{\mathbf{RADA1}\left(a_0, ht_{lim} - htdum_i\right)}.$$

   A temporary maximum propagation angle Θ_{75a} is then set equal to a_1.

   c. The current refractivity level i is incremented by 1. If one of the conditions in step 2 has been met, then the SU proceeds to step 3; otherwise, steps 2a through 2c are repeated.

3. If h_0 is less than ht_{lim} and i_{flag} is equal to 0, then propagation angle a_1 at ht_{lim} is re-computed as

$$a_1 = \sqrt{\mathrm{RADA1}\left(a_0, ht_{lim} - h_0\right)}$$

   and the variable Θ_{75a} is then set equal to a_1.

4. The propagation angle and range a_1 and r_1 are now re-computed from

$$a_1 = \sqrt{\mathrm{RADA1}\left(a_0, htdum_{lvlep} - h_0\right)},$$
$$r_1 = \mathrm{RP}\left(r_0, a_1 - a_0\right),$$

and the effective earth radius a_{ek}, the effective earth radius factor e_k, and twice the effective earth radius, *twoka* are given by

$$a_{ek} = \frac{r_1}{a_1 - a_{start}},$$
$$twoka = 2\,a_{ek},$$
$$e_k = 6.37 \times 10^{-6}\,a_{ek}.$$

If using the airborne hybrid model and the calling SU is the APMINIT CSC, then twice the effective earth radius factor is computed for a downward ray where the initial launch angle is $-a_{start}$. Steps 1 through 2a are repeated with a_1 negative, i decremented by 1, and $htdum_{i+1}$ replaced with $htdum_i$. Finally, the variable $twoka_{down}$ is computed from

$$twoka_{down} = \frac{2\,r_1}{a_1 + a_{start}},$$

and Θ_{75} is determined from

$$\Theta_{75} = \mathbf{MAX}\left(\Theta_{75a}, a_{start}\right).$$

Table 30 and Table 31 provide identification, description, units of measure, and show the computational source for each input and output data element, respectively, of the GET_K SU.

Table 30. GET_K SU input data element requirements.

Name	Description	Units	Source
a_{crit}	Critical angle (angle above which no rays are trapped)	radians	REFINIT SU
a_{launch}	Launch angle used which, when traced, separates the PE and XO regions from the RO region	radians	GETTHMAX SU
ant_{ref}	Transmitting antenna height relative to the reference height h_{minter}	meters	TERINIT SU
μ_{bwr}	Antenna vertical beam width	radians	APMINIT CSC
μ_{or}	Antenna pattern elevation angle	radians	APMINIT CSC
f_{ter}	Logical flag indicating if terrain profile has been specified: ‘.true.’ = terrain profile specified ‘.false.’ = terrain profile not specified	N/A	APMINIT CSC
grdum	M-unit gradient array	(M-unit/ meter)	REFINIT SU
hmref	Height relative to h_{minter}	meters	TERINIT SU
htdum	Height array for current interpolated profile	meters	REFINIT SU
ht_{lim}	User-supplied maximum height relative to h_{minter}, i.e., $ht_{lim} = h_{max} - h_{minter}$	meters	TERINIT SU

Table 30. GET_K SU input data element requirements. (continued)

Name	Description	Units	Source
i_{hybrid}	Integer indicating which sub-models will be used: 0 = (FEDR + PE) model 1 = full hybrid model (PE + FE + RO + XO) 2 = partial hybrid model (PE + XO)	N/A	APMINIT CSC
i_{org}	Integer flag indicating origin of calling SU 0 = called from APMINIT CSC 1 = called from TROPOINIT SU	N/A	APMINIT CSC TROPOINIT SU
i_{start1}	Refractivity level index within *htdum* at ant_{ref}	N/A	REFINIT SU
lvlep	Number of refractivity levels in profile *htdum*, *refdum*	N/A	REFINIT SU
y_{fref}	Ground elevation height at the source	meters	APMINIT CSC

Table 31. GET_K SU output data element requirements.

Name	Description	Units
a_{ek}	Effective earth radius	meters
e_k	Effective earth radius factor	N/A
Θ_{75}	75% of maximum propagation angle in PE calculations	radians
twoka	Twice the effective earth radius	meters
$twoka_{down}$	Twice the effective earth radius for downward path	meters

5.1.13 Get Alpha Impedance (GETALN) SU

The GETALN SU computes the surface impedance term in the Leontovich boundary condition and the complex index of refraction for finite conductivity. The implementation of these impedance formulas follow Kuttler and Dockery‘s method (1991).

Upon entering the SU, the smooth surface impedance term α is computed from the complex dielectric constant nc^2 and free space wavenumber k_o, for both vertical and horizontal polarization, by

$$\alpha_h = ik_o\sqrt{nc_{i_g}^2 - 1},$$

$$\alpha_v = ik_o\frac{\sqrt{nc_{i_g}^2 - 1}}{nc_{i_g}^2}$$

where I is the imaginary number $\sqrt{-1}$.

If a frequency less than 50 MHz has been specified (HF_{flag} = '.true.'), then the SURFIMP SU is referenced to compute the effective surface impedance, ζ, over sea-water. The surface impedance term for vertical polarization is then computed as

$$\alpha_v = ik_o\zeta$$

over seawater, and for those portions of the path over land, it is computed as

$$\alpha'_{h,v} = ik_o \,\mathbf{SIN}\,\psi \frac{1-\Gamma_{h,v}}{1+\Gamma_{h,v}}$$
$$\alpha_{h,v} = \mathbf{COS}(\beta)\left(\alpha'_{h,v} + slp\left(1/\mathbf{COS}(\beta) - \mathbf{COS}\,\psi \right)\right)$$

where

$$\beta = \mathbf{TAN}^{-1}(slp)$$

and *slp* is the slope of the terrain segment at the current range. For a non-zero grazing angle the rough surface reflection coefficient, Γ, is determined from referencing the GETREFCOEF SU.

For frequencies above 50 MHz, and if rough surface calculations are required (*ruf* = '.true.'), then if a non-zero grazing angle ψ exists for the current range step, the surface impedance is computed as

$$\alpha_{h,v} = ik_o \,\mathbf{SIN}\,\psi \frac{1-\Gamma_{h,v}}{1+\Gamma_{h,v}},$$

where the subscripts *h,v* indicate horizontal and vertical polarization quantities, respectively.

If using the central difference algorithm (i_{alg} = 1), follow steps 1 through 2 to compute constants and variables for subsequent use in the MIXEDFT SU.

1. The determination of the complex root, R_T, of the quadratic equation for the mixed transform method is based on Kuttler's formulation:

$$R_T = -\sqrt{1.0 + (\alpha_h \Delta z_{PE})^2} - \alpha_h \Delta z_{PE} \quad \text{for horizontal polarization,}$$
$$R_T = \sqrt{1.0 + (\alpha_v \Delta z_{PE})^2} - \alpha_v \Delta z_{PE} \quad \text{for vertical polarization}$$

2. Next, the array *rn* is determined according to

$$rn_i = R_T^i \,. \quad I = 1, 2, \ldots n_{fft}.$$

Several parameters used in the central difference algorithm are now computed:

$$R_k = \frac{2(1 - rn_2)}{(1 + rn_2)\left(1 - rn_{n_{fft}}^2\right)},$$

$$C_{1x} = e^{i\Delta r_{PE}\left(\sqrt{k_o^2 + \left(\frac{\mathbf{LN}(R_T)}{\Delta z_{PE}}\right)^2} - k_o\right)},$$

$$C_{2x} = e^{i\Delta r_{PE}\left(\sqrt{k_o^2 + \left(\frac{\mathbf{LN}(R_T) - i\pi}{\Delta z_{PE}}\right)^2} - k_o\right)}.$$

If using the backward difference algorithm (i_{alg} = 2), R_T is computed as

$$R_T = \frac{1}{(1 + \alpha_{h,v}\Delta z_{PE})},$$

the array *rn* is computed as in step 2 above, and the parameter $cmft_x$ is computed using the same equation for C_{1x} in step 2 above.

Table 32 and Table 33 provide identification, description, units of measure, and the computational source for each GETALN SU input and output data element.

Table 32. GETALN SU input data element requirements.

Name	Description	Units	Source
Δr_{PE}	PE range step	meters	PEINIT SU
Δz_{PE}	Bin width in z space	meters	FFTPAR SU
f_{MHz}	Frequency	MHz	APM_MOD
fter	Logical flag indicating if terrain profile has been specified: ‘.true.’ = terrain profile specified ‘.false.’ = terrain profile not specified	N/A	APMINIT CSC
HFflag	HF computation flag indicating the frequency specified is less than 50 MHz	N/A	APMINIT CSC

Table 32. GETALN SU input data element requirements. (continued)

Name	Description	Units	Source
i_{alg}	Integer flag indicating which DMFT algorithm is being used: 0 = no DMFT algorithm will be used 1 = use central difference algorithm 2 = use backward difference algorithm	N/A	APMINIT CSC
i_g	Counter indicating current ground type being modeled	N/A	APMINIT CSC PESTEP SU
i_{pol}	Polarization flag: 0 = horizontal polarization 1 = vertical polarization	N/A	Calling CSCI
k_o	Free-space wavenumber	meters^{-1}	APMINIT CSC
nc^2	Array of complex dielectric constants	N/A	DIEINIT SU
n_{fft}	Transform size	N/A	FFTPAR SU
ψ	Grazing angle	radians	Calling SU
r	Current calculation range	meters	Calling SU
rngwind	Ranges of wind speeds entered: $rngwind_i$ = range of i^{th} wind speed	meters	Calling CSCI
ruf	Logical flag indicating if rough sea surface calculations are required '.true.' = perform rough sea surface calculations '.false.' = do not perform rough sea surface calculations	N/A	APMINIT CSC
slp	Slope of the terrain segment at the current range.	N/A	TERINIT SU
wind	Array of wind speeds	meters/ sec	Calling CSCI

Table 33. GETALN SU output data element requirements.

Name	Description	Units
$\alpha_{h,v}$	Surface impedance term for horizontal and vertical polarization	N/A
C_{1x}	Constant used to propagate c_{k1} by one range step in central difference algorithm	N/A
C_{2x}	Constant used to propagate c_{k2} by one range step in central difference algorithm	N/A
$cmft_x$	Constant used to propagate *cmft* by one range step in backward difference algorithm	N/A
R_k	Coefficient used in c_{k1} and c_{k2} calculations.	N/A
rn	Array of R_T to the i^{th} power (e.g., $rn_i = R_T^i$)	N/A
RT	Complex root of quadratic equation for mixed transform method based on Kuttler's formulation	N/A

5.1.14 Get Angles (GETANGLES) SU

The GETANGLES SU computes grazing angles at each PE range step via ray trace and spectral estimation for subsequent use in rough sea surface calculations. This SU is referenced only if l_{graze} is '.true.'. This flag is set to '.true.' for any number of conditions that require grazing angle calculations, such as rough surface, HF frequency has been specified, clutter calculations are desired, and if *lang* is specified as '.true.'.

Upon entering the SU, the RGTRACE SU is referenced to determine the grazing angles ψ_{ray} from ray trace.

If a terrain profile has been specified (f_{ter} = '.true.') and a surface-based duct has been specified (l_{duct} = '.true.') then the grazing angles ψ_{PE} are computed from spectral estimation of the near-surface PE field by running the PE algorithm out to the maximum range r_{max}, assuming horizontal polarization and smooth surface conditions (i.e., no wind speed).

First, the array ψ_{PE} is allocated for size of i_{PE}—equal to the number of PE range steps required to propagate the field out to r_{max}. The array is initialized to zero, with the first element initialized to $\pi/2$ radians. If the propagation angles and factors are to be computed (*lang* = '.true.') then the appropriate arrays are allocated and initialized. The TRACE_ROUT SU is then referenced to trace one ray at the maximum calculation angle. The current PE range r and PE integer step i_{PEstp} are then set equal to zero, with the terrain height y_{last} at the previous range step set equal to tyh_0 if a terrain profile has been specified, or 0 otherwise. An iterative DO WHILE loop is then begun to advance the PE solution such that for the current PE range, a PE solution is calculated from the solution at the previous PE range. This iterative procedure is repeated in the DO WHILE loop until r is greater than r_{max}. The following steps (1 through 5) are performed for each PE range step within the DO WHILE loop.

1. The current PE calculation range r is incremented by one PE range step, Δr_{PE} and the PE range step counter i_{PEstp} is incremented by 1. The range at which interpolation for range-dependent refractivity profiles is performed, r_{mid}, is also incremented by one-half the PE range step.

2. If performing a terrain case (f_{ter} = '.true.'), the ground heights, y_{cur} and y_{curm}, at range r and r_{mid}, respectively, are determined according to

$$y_{cur} = tyh_{i_{PEstp}} ,$$
$$y_{curm} = 1/2\left(tyh_{i_{PEstp}-1} + y_{cur}\right).$$

   If y_{cur} is less than y_{curm}, the DOSHIFT SU is referenced to adjust the PE field relative to the terrain height.

The PE field array U is now propagated in free space one range step by referencing the FRSTP SU.

If the APM CSCI is used in a range-dependent mode (i.e., the number of profiles n_{prof} is greater than 1), or a terrain profile is specified, the REFINTER SU is referenced to compute a new modified refractive index profile, *profint*, adjusted by the local ground height y_{curm} at range r_{mid}. A new environmental phase array, *envpr*, based on this new refractivity profile is then computed from

$$envpr_j = e^{i \Delta r_{PE} profint_j}; \; j=1,2,\ldots n_{fft}$$

$$envpr_j = filt_{j-n_{34}} envpr_j ; \quad j = n_{34}, n_{34}+1, n_{34}+2, \ldots n_{fft}$$

3. The complex field U is now multiplied by the environmental phase array for all bins from 0 through n_{fft}-1.

4. Next, if a terrain profile has been specified and the terrain slop is positive ($y_{cur} > y_{curm}$), the DOSHIFT SU is referenced to adjust the PE field relative to the terrain height.

5. The SPECEST SU is then referenced to determine the grazing angle ϑ_{out} and this angle is stored in array ψ_{PE}. If no terrain has been specified and the range is greater than the horizon range r_{hor}, then the grazing angle stored is the smaller of the tangent angle a_{cut} or ϑ_{out}.

6. This step is performed only if *lang* is '.true.'. The propagation angle at select height points, as long as they are less than the height defined by the ray traced at the maximum calculation angle, are computed by referencing the SPECEST SU. These are then stored in array Θ_p .

Finally, i_{gPE}, the number of grazing angles computed, is initialized to i_{PE} and the SU is exited.

Table 34 and Table 35 provide identification, description, units of measure, and the computational source for each GETANGLES SU input and output data element.

Table 34. GETANGLES SU input data element requirements.

Name	Description	Units	Source
a_{cut}	Tangent angle from antenna height to radio horizon	radians	PEINIT SU
ant_{ref}	Transmitting antenna height relative to the reference height h_{minter}	meters	TERINIT SU
Δr_{PE}	PE range step	meters	PEINIT SU
Δr_{PE2}	½ PE range step	meters	PEINIT SU
$filt$	Cosine-tapered (Tukey) filter array	N/A	PEINIT SU
f_{ter}	Logical flag indicating if terrain profile has been specified: '.true.' = terrain profile specified '.false.' = terrain profile not specified	N/A	APMINIT CSC
ht_{lim}	User-supplied maximum height relative to h_{minter}, i.e., $ht_{lim} = h_{max} - h_{minter}$	meters	TERINIT SU
h_{trap}	Height of the highest trapping layer from all refractivity profiles	meters	REFINIT SU
i_{hybrid}	Integer indicating which sub-models will be used: 0 = pure PE model 1 = full hybrid model (PE + FE + RO + XO) 2 = partial hybrid model (PE + XO)	N/A	APMINIT CSC
i_{PE}	Number of PE range steps	N/A	PEINIT SU
$lang$	Propagation angle and factor output flag '.true.'= Output propagation angle and propagation factor for direct and reflected ray (where applicable). '.false.' = Do not output propagation angles and factors	N/A	Calling CSCI
l_{duct}	Logical flag indicating if surface-based duct profile has been specified '.true'. = surface-based duct exists '.false.' = no surface-based duct exists	N/A	REFINIT SU
l_{evap}	Logical flag indicating if evaporation duct profile has been specified '.true'. = evaporation duct exists '.false.' = no evaporation duct exists	N/A	REFINIT SU
n_{fft}	Transform size	N/A	FFTPAR SU
n_{34}	¾ n_{fft}	N/A	PEINIT SU
n_{f4}	¼ n_{fft}	N/A	PEINIT SU
n_{prof}	Number of refractivity profiles	N/A	Calling CSCI
r_{hor}	Radio horizon range	meters	PEINIT SU
r_{max}	Maximum specified range	meters	Calling CSCI
ϑ_{mxg}	Maximum PE calculation angle for spectral estimation of grazing angles	radians	APMINIT CSC

Table 34. GETANGLES SU input data element requirements. (continued)

Name	Description	Units	Source
tyh	Adjusted height points of sampled terrain profile at every PE range step	meters	TERINIT SU

Table 35. GETANGLES SU output data element requirements.

Name	Description	Units
Δz_{spec}	Height increment at which the propagation angles are computed from spectral estimation	meters
l_{spec}	Logical flag indicating if grazing angles need to be computed via spectral estimation. '.true.' = compute grazing angles by spectral estimation '.false.' = do not compute grazing angles by spectral estimation	N/A
n_{ang}	Number of points in the vertical at which to spectrally estimate propagation angles.	N/A
ψ_{PE}	Array containing grazing angles computed from spectral estimation of PE field	radians
ψ_{ray}	Two-dimensional array containing grazing angles and corresponding ranges computed from ray trace	radians, meters
i_{error}	Integer variable indicating error number for ALLOCATE and DEALLOCATE statements	N/A
i_{gPE}	Number of grazing angles computed from spectral estimation	N/A
i_{grz}	Number of grazing angles computed from ray trace	N/A
Θ_p	Two-dimensional array containing the propagation angle estimated from PE at n_{ang} height points and at every PE calculation range step during the initialization routine. Format is $\Theta_p(i,j)$ = propagation angle at the i^{th} height point (i=1 to n_{ang}) and j^{th} PE range step (j = 0 to i_{gPE}).	radians

5.1.15 Get Maximum Angle (GETTHMAX) SU

The GETTMAX SU performs an iterative ray trace to determine the minimum angle required (based on the reflected ray) in obtaining a PE solution. The determination of this angle depends on the particular mode of execution. For full and partial hybrid modes, a ray is traced up to a height that exceeds at least 20% above the maximum terrain peak along the path or the highest trapping layer specified in the environment profiles, whichever is greater. Heights and angles of this ray are stored at each output range. The maximum PE propagation angle, Θ_{max}, is then determined from the local maximum angle of the traced ray. For the full hybrid mode, the minimum PE propagation angle is required to meet the following criteria: (1) the top of the PE region must contain all trapping layers for all refractivity profiles, (2) the top of the PE region must be at least 20% higher than the highest peak along the terrain profile, and (3) the minimum PE propagation angle must be at least as large as the grazing angle of the limiting ray ψ_{lim}.

First, four in-line ray trace functions are defined for general parameters a, b, c, and g_{rd}:

$$\mathbf{RADA1}(a,b)=a^2+2g_{rd}b\ ,$$
$$\mathbf{RP}(a,b)=a+\frac{b}{g_{rd}}\ ,$$
$$\mathbf{AP}(a,b)=a+bg_{rd}\ ,$$
$$\mathbf{HP}(a,b,c)=a+\frac{b^2-c^2}{2g_{rd}}\ .$$

The first parameter to be determined is the minimum PE angle limit a_{mlim}. The parameter to be determined later, Θ_{max}, must be at least this value. The initial estimate of a_{mlim} is given by

$$a_{mlim}=\pi/90\left(.37541+4.331e^{\frac{-f_{MHz}}{248.4}}+1.42e^{\frac{-f_{MHz}}{2867}}+.4091e^{\frac{-f_{MHz}}{2495}}\right).$$

If the DMFT algorithm is not required based on the specified inputs, the propagation path is entirely over water and no rough surface calculations are required, then a_{mlim} is decreased by ½.

For a specific height-finder antenna pattern (i_{pat} = 6), the PE angle limit is re-computed as

$$\begin{aligned} a_{mlim} &= \pi/180\left(4.36985 - 1.02784\, f_{GHz} + 0.0786\, f_{GHz}{}^2\right) && \textit{for } f_{GHz} < 6.0 \\ a_{mlim} &= \pi/180\left(2.3 - 0.1\, f_{GHz}\right) && \textit{for } f_{GHz} \geq 6.0 \end{aligned},$$

where f_{GHz} is the frequency in gigahertz. If rough surface calculations are to be performed and if a surface-based duct has been specified, then a_{mlim} is doubled.

If the backward difference DMFT algorithm will be used, then a_{mlim} is adjusted to accommodate low antenna heights according to

$$a_{mlim}=\mathbf{MAX}\left(a_{mlim}, \mathbf{SIN}^{-1}\left(\frac{\lambda}{2\,ant_{ht}}\right)\right).$$

A multiplicative height factor h_{mt} is determined to ensure clearance of the ray path for low antenna heights over large terrain elevations:

$$h_{mt} = \mathbf{MIN}\left(.2, \frac{ant_{ht}}{\mathbf{MAX}(ty_1, 1)} \right).$$

If h_{mt} is less than 0.1, then it is set equal to 0. It is then increased by 1.

Several constants needed in subsequent steps in this SU are determined. An initial estimate of the launch angle a_{launch}, is initialized to α_{lim}, the elevation angle of the RO limiting ray. If using the full hybrid mode, then a_{launch} is set equal to the negative of a_{launch}. The maximum height to trace to, z_{limt}, is set equal to ht_{lim}-10^{-5}, and the range step, Δr_{temp}, for subsequent ray tracing is given by $r_{max}/200$. The terrain elevation height at the source, y_{nt}, is initialized to ty_1, provided APM is running in a full hybrid mode and ty_1 is greater than zero; otherwise, y_{nt} is initialized to 0.

An iterative ray trace to determine the launch angle a_{launch} and subsequently Θ_{max} is then begun. Steps 1 through 3 are performed until a ray has been safely traced from height ant_{ref} to z_{limt}.

1. At the start of the ray trace, the current local angle (a_0), range (r_0), height (h_0), and refractive gradient index (j) are initialized to a_{launch}, 0, ant_{ref}, and i_{start1}, respectively. The counter index, kt, for the terrain profile arrays tx and ty is initialized to one. The variable r_o, the current output range to trace to, is set equal to zero. Steps 1.a through 1.d are then performed for each ray trace step from 1 to i_{rtemp}.

   a. First, r_o is incremented by Δr_{temp}. Now steps i through vii are performed until r_0 reaches r_o.

      i. The range at the end of the ray trace step, r_1, is set equal to r_o, and the current refractive gradient g_{rd} is set equal to $grdum_j$

      ii. The angle at the end of the trace, a_1, is then given by

$$a_1 = \mathrm{AP}(a_0, r_1 - r_0).$$

      iii. If a_1 is of the opposite sign of a_0, then a_1 is set to zero and r_1 is given by

$$r_1 = \mathrm{RP}(r_0, a_1 - a_0).$$

      iv. The height at the end of the ray trace h_1 is given by

$$h_1 = \mathbf{HP}(h_0, a_1, a_0).$$

v. If a_1 is positive and h_1 has reached or surpassed the next height level, then a_1, r_1, j, and h_1 are found as follows. First, h_1 is set equal to $htdum_{j+1}$, and a_1 and r_1 are given by

$$\begin{aligned} a_1 &= \sqrt{\mathbf{RADA1}(a_0, h_1 - h_0)} \\ r_1 &= \mathbf{RP}(r_0, a_1 - a_0) \end{aligned}.$$

The index j is incremented by one, and the height, h_1, at the end of the ray trace step is given by the smaller of ht_{lim} or $htdum_j$.

vi. However, if either of the conditions for a_1 and h_1 in step v are not met, and a_1 is less than or equal to 0, then h_1 is set equal to y_{nt} if the calculated value in step iv is less than y_{nt}. If the calculated value of h_1 in step iv is less than $htdum_j$, then h_1 is set equal to $htdum_j$, and j is set equal to the maximum of 0 or j-1 . The variables a_1 and r_1 are then determined from

$$\begin{aligned} a_1 &= -\sqrt{\mathbf{RADA1}(a_0, h_1 - h_0)} \\ r_1 &= \mathbf{RP}(r_0, a_1 - a_0) \end{aligned}.$$

vii. If the ray has hit the surface and is reflected, which would be the condition for which h_1 is set equal to y_{nt} in step vi, then a_1 is set equal to minus a_1, ψ_{lim} is set equal to a_1, the range, r_{pest} (at which loss values from the PE model will start being calculated) is set equal to r_1, and the height h_{start} is set equal to y_{nt}. The variable h_{start} is used for subsequent initialization of ray tracing to fill in array h_{lim}. In preparation for the next ray trace step; h_0 is set equal to h_1, r_0 is set equal to r_1, and a_0 is set equal to a_1. If the range r_1 is greater than r_{flat}, then the current iteration is exited and the SU proceeds to step b; otherwise, steps i through vii are repeated until r_0 reaches r_o.

b. If running a terrain case (f_{ter} = '.true.'), at the end of the ray trace for the current step, a check is made to see that the current height of the ray is at least 20% higher than the current terrain height. The counter kt is determined such that $r_0 > tx_{kt+1}$ and $kt < i_{tpa}$. If using the partial hybrid mode and range r_0 is less than 5 km, then the clearance height of the terrain, y_n, at the current range for the traced ray, is given by

$$y_n = h_{mt}\left[ty_{kt} + slp_{kt}(r_0 - tx_{kt})\right].$$

If the previous conditions are not met, then h_{mt} in the above equation is replaced with the constant 1.2.

c. The ending angle, range, and height for each ray trace step is now stored in arrays *raya*, *rtemp*, and *htemp*, respectively.

d. Now, if running a full hybrid case (i_{hybrid} = 1), a test is made to determine if both h_0 is less than y_n and if r_0 is greater than r_{flat}. If these conditions are true, then the flag i_{quit} is set equal to 1. If the case is not a full hybrid case and if h_0 is less than y_n, then i_{quit} is set equal to 1. Finally, if h_0 is greater than or equal to z_{limt}; or i_{quit} equals 1, then the current iteration is exited and the SU proceeds to step 2; otherwise, steps 1.a through 1.d are repeated.

2. If the iteration defined by steps 1.a through 1.d has been prematurely terminated (i_{quit}=1), then the initial elevation angle a_{launch} is decreased by 10^{-3} radians for the full hybrid case (i_{hybrid}=1), and is increased by 10^{-3}, otherwise. If the previous iteration has not been prematurely terminated (i_{quit}=0), the SU continues with step 3.

3. If height z_{limt} is reached, then an initial launch angle (i.e., ray) has been found with all traced heights, ranges, and angles stored. The integer flag to continue ray tracing, i_{ray}, is set to equal 1 to terminate the iterative loop, and the index i_{hmax}, indicating the range step at which z_{limt} is reached, is set equal to the range step index i (the range step index counter in the iterative loop defined by steps 1 through 3.

The remaining elements from i_{hmax} to i_{rtemp} in arrays *htemp*, *rtemp*, and *raya* are filled with the values h_0, r_{max}, and a_0, respectively. Next, the index i_{hmax} is set equal to the minimum of i_{hmax} or i_{rtemp}.

The variable Θ_{max} is found for the PE region based on the local ray angles just determined for the particular ray traced. First, the index i_{ap} at which the local ray angle becomes positive (i.e., $raya_{i_{ap}}$) is determined. If i_{ap} equals i_{rtemp} this indicates that no PE calculations are required for the specific geometry, in which case the flag no_{PE} is set equal to 1, Θ_{75} is set equal to a_{mlim}, r_{pest} is set equal to r_{max}, z_{lim} is set equal to ht_{lim}, and the SU is exited . Otherwise, several variables are next initialized. The local indices, i_{ok} and i_{flag}, plus the variables z_{lim} and a_{mxcur}, are each set equal to zero. The variable a_{mxcur} is the maximum local angle along the traced ray up to height z_{lim} with a minimum limit of a_{mlim}.

The variable Θ_{max} is then found from an iteration performed on the local angle and height at which the local maximum angle is reached. The following steps 1 through 6 are performed while the flag i_{ok} is 0.

1. The height in the PE region that must be reached for the hybrid model is z_{test}. The first occurrence of $htemp_j$ that is greater than z_{test} is found and the index i_{st} is then set to the smaller of the index j where this occurs or i_{hmax}.

2. The angle a_{mxcur} is now initialized to $raya_1$. The maximum angle in *raya* is then found looking only at elements from $raya_2$ to $raya_{i_{st}}$ and a_{mxcur} is set equal to this angle.

3. a_{mxcur} is now set equal to the maximum of a_{mlim} and a_{mxcur}. The variable a_{temp} is now set to a_{mxcur} divided by 0.75. If using the partial hybrid mode (i_{hybrid}=2), z_{test} is given by

$$z_{test} = \mathbf{MAX}\left(ant_{ref}\,, h_{test}\,, 1.2\,h_{termax}\,, 10^3\right).$$

4. A reference is then made to the FFTPAR SU to determine new values for z_{test}, z_{max}, Δz_{PE}, ln_{fft}, and n_{fft} using the inputs: ln_{min}, λ, a_{temp}, and i_{flag}.

5. After the reference to the FFTPAR SU is made, if i_{flag} = 0 it is set equal to 1. In addition, if not running a full hybrid case, i_{ok} is set equal to 1. However, if after the reference to the FFTPAR SU is made, i_{flag} is equal to one and if the case is not a partial hybrid case; the iterative height tolerance *tol* is given by

$$tol = \frac{\left|z_{test} - z_{lim}\right|}{z_{test}} .$$

   A test is then made to determine whether this value of *tol* is less than or equal to z_{tol}, the height tolerance for Newton's method. If it is, then the index i_{ok} is set equal to one.

6. Now z_{lim} is set equal to z_{test} and if i_{ok} is 0, steps 1 through 6 are repeated. Otherwise, the SU proceeds to the next step.

The variable Θ_{75} is now set equal to a_{mxcur}, and Θ_{max} is set equal to a_{temp}. The variable ln_{fft} is then adjusted such that for every 5° in Θ_{75}, it is increased by 1.

Next, the TRACE_ROUT SU is referenced to trace the ray to each output range step, Δr_{out}, storing heights in array *hlim*. If running in a full hybrid mode, the ray is traced from starting angle, range, and height equal to ψ_{lim}, r_{pest}, and h_{start}, respectively. Otherwise, the starting angle, range, and height are equal to a_{launch}, 0, and ant_{ref}, respectively.

Before exiting, all elements of *hlim* corresponding to ranges less than r_{pest} are set equal to y_{fref}.

Table 36 and Table 37 provide identification, description, units of measure, and the computational source for each GETTHMAX SU input and output data element.

Table 36. GETTHMAX SU input data element requirements.

Name	Description	Units	Source
α_{lim}	Elevation angle of the RO limiting ray	radians	Calling SU
ant_{ht}	Transmitting antenna height above local ground	meters	Calling CSCI
ant_{ref}	Transmitting antenna height relative to h_{minter}	meters	TERINIT SU
f_{MHz}	Frequency	MHz	Calling CSCI
f_{ter}	Logical flag indicating if terrain profile has been specified: '.true.' = terrain profile specified '.false.' = terrain profile not specified	N/A	APMINIT CSC
grdum	M-unit gradient array	(M-unit/ meter)	REFINIT SU
htdum	Height array for current interpolated profile	meters	REFINIT SU
h_{termax}	Maximum terrain height along profile path	meters	Calling SU
h_{test}	Minimum height at which all trapping refractivity features are below	meters	Calling SU
htlim	User specified maximum height relative to h_{minter}	meters	TERINIT SU
ihybrid	Integer indicating which sub-models will be used: 0 = FEDR+PE models 1 = full hybrid model (PE + FE + RO + XO) 2 = partial hybrid model (PE + XO)	N/A	APMINIT CSC
i_{alg}	Integer flag indicating which DMFT algorithm is being used: 0 = no DMFT algorithm will be used 1 = use central difference algorithm 2 = use backward difference algorithm	N/A	APMINIT CSC
i_{rtemp}	Temporary number of range steps (used for ray tracing)	N/A	APM_MOD
i_{start1}	Refractivity level index within *htdum* at ant_{ref}	N/A	REFINIT SU
i_{tpa}	Number of terrain points in used internally in arrays *tx* and *ty*	N/A	APMINIT CSC
λ	Wavelength	meters	APMINIT CSC
lnmin	Minimum power of 2 transform size	N/A	APMINIT CSC
n_{rout}	Integer number of output range points desired	N/A	Calling CSCI
r_{flat}	Maximum range at which the terrain profile remains flat from the source	meters	Calling SU
r_{max}	Maximum output range	meters	Calling CSCI
rngout	Array containing all desired output ranges	meters	APMINIT CSC

Table 36. GETTHMAX SU input data element requirements. (continued)

Name	Description	Units	Source
ruf	Logical flag indicating if rough sea surface calculations are required '.true.' = perform rough sea surface calculations '.false.' = do not perform rough sea surface calculations	N/A	APMINIT CSC
slp	Slope of each segment of terrain	N/A	TERINIT SU
tx	Range points of terrain profile	meters	TERINIT SU
ty	Adjusted height points of terrain profile	meters	TERINIT SU
y_{fref}	Ground elevation height at source	meters	APMINIT CSC
z_{lim}	Height limit for PE calculation region	meters	APMINIT CSC
z_{test}	Height in PE region that must be reached for hybrid model	meters	Calling SU
z_{tol}	Height tolerance for Newton's method	meters	APMINIT CSC

Table 37. GETTHMAX SU output data element requirements.

Name	Description	Units
a_{launch}	Launch angle used which, when traced, separates PE and XO regions from the RO region	radians
$hlim$	Array containing height at each output range separating the RO region from the PE (at close ranges) and XO (at far ranges) regions	meters
$htemp$	Heights at which ray is traced to every range in $rtemp$	meters
i_{ap}	Index indicating when the local ray angle becomes positive in array $raya$	N/A
i_{err}	Return error code	N/A
ln_{fft}	Power of 2 transform size, i.e. $n_{fft}=2^{ln_{fft}}$	N/A
no_{PE}	Integer flag indicating if PE calculations are needed: 0 = PE calculations needed 1 = no PE calculations needed	N/A
ψ_{lim}	Grazing angle of limiting ray	radians
$raya$	Array containing all local angles of traced ray alaunch at each i_{rtemp} range	radians
r_{pest}	Range at which loss values from the PE model will start being calculated	meters
$rtemp$	Range steps for tracing to determine maximum PE angle	meters
Θ_{max}	Maximum propagation angle in PE calculations	radians
Θ_{75}	75% of maximum propagation angle in PE calculations	radians
z_{max}	Maximum height in PE calculation region	meters

5.1.16 Grazing Angle Interpolation (GRAZE_INT) SU

The GRAZE_INT SU interpolates, for each PE range step, grazing angles computed from both ray trace and spectral estimation. Those angles from ray trace take precedence.

Upon entering the SU, the grazing angle array Ψ is allocated for size i_{PE} and initialized to 0, with the first element initialized to ½π radians. Several variables are next initialized. The variable r which is the range to interpolate to, is initialized to Δr_{PE}. The range r_{grz} at which the spectrally estimated angles were computed in the GETANGLES SU is initialized to Δr_{grz}.

If a surface-based duct has been specified, no evaporation duct exists, and the range r_{flat} is greater than the horizon range r_{hor}, then a check is made for the possible existence of a skip zone produced by a surface-based duct. If one exists, then the spectrally estimated grazing angles will be included in the interpolation algorithm for those ranges beyond the start of the skip zone. The check for a skip zone is done by performing an iterative loop on the ranges r_{ray} corresponding to the grazing angles in ψ_{ray}. For those ranges beyond r_{hor} the maximum difference between successive ranges in r_{ray} is determined according to

$$r_{skip} = \text{maximum of } \left(r_{ray_{j+1}} - r_{ray_j} \right); \quad \text{for } j = k\text{-1}, k, \ldots i_{grz}\text{-1},$$

where k is the first element in r_{ray} corresponding to the first range beyond r_{hor}. If r_{skip} is greater than 5 km, then a skip zone is assumed to exist and the range *per* at which spectrally estimated grazing will be included in the interpolation algorithm is set equal to the minimum of r_{flat} or r_{end}, where r_{end} is the first range point in r_{ray} just beyond the skip zone. If no skip zone exists, then *per* is set equal to r_{max}. Next, the following steps 1 through 3 are performed for each PE range step i, indexed from 1 to i_{PE}.

1. For range r less than r_{hor} steps 1.a through 1.c are performed; otherwise, the SU proceeds to step 2.

    a. An iterative loop is performed to find k, the element in r_{ray} corresponding to the first range point beyond r_{hor}.

    b. For k equal to 1 the grazing angle is determined as

$$\Psi_i = \left| \mathbf{TAN}^{-1}\left(\frac{s}{r}\right) \right|,$$

$$s = h_{mref} - y_{fref} + ant_{ht} - \frac{r^2}{2a_{ekst}}.$$

c. For all other values of k the grazing angle is determined as

$$\Psi_i = \mathbf{MAX}(0, \psi),$$
$$\psi = \psi_{ray_{k-1}} + \psi_{ray_k}\left[\frac{r - r_{ray_{k-1}}}{r_{ray_k} - r_{ray_{k-1}}}\right].$$

2. For range r greater than r_{hor} an iterative loop is performed to determine the number of elements icr within array r_{ray} satisfying the condition $rmd < r_{ray} < rmd + \Delta r_{PE}$, where rmd is the range at mid-PE range step. The following steps a through b are then performed.

   a. If icr is non-zero, then the indices $jr1$ and $jr2$ are initialized such that ranges $r_{ray_{jr1}}$ through $r_{ray_{jr2}}$ satisfies the condition in step 2 and $jr2$-$jr1$ equals icr. If $r_{ray_{jr2}}$ is greater than range r, then the grazing angle Ψ_i is interpolated as

$$\Psi_i = \psi_{ray_j} + \psi_{ray_{j+1}}\left[\frac{r - r_{ray_j}}{r_{ray_{j+1}} - r_{ray_j}}\right]$$

   where the index j lies between $jr1$ and $jr2$ and is defined such that r_{ray_j} is the nearest range point less than r and $r_{ray_{j+1}}$ is the nearest range point greater than r. If $r_{ray_{jr2}}$ is less than r, then the grazing angle Ψ_i is averaged according to

$$\Psi_i = \left(\frac{1}{icr}\right)\sum_{j=jr1}^{jr2}\psi_j$$

   b. If icr is equal to 0 and r is greater than per, then grazing angle Ψ_i is computed from interpolation of angles ψ_{PE} determined from spectral estimation. If no spectrally estimated angles exist, then Ψ_i is set equal to 0. If an evaporation duct profile has been specified, then Ψ_i is set equal to $\psi_{ray_{i_{grz}}}$.

3. Both rmd and r are then incremented by Δr_{PE}.

Once all grazing angles Ψ have been determined, the arrays ψ_{ray} and ψ_{PE} are deallocated and the SU is exited.

Table 38 and Table 39 provides identification, description, units of measure, and the computational source for each GRAZE_INT SU input and output data element.

Table 38. GRAZE_INT SU input data element requirements.

Name	Description	Units	Source
a_{cut}	Tangent angle from antenna height to radio horizon	radians	PEINIT SU
a_{ekst}	$\frac{4}{3}$ times mean earth radius	meters	APM_MOD
ant_{ht}	Transmitting antenna height above local ground	meters	Calling CSCI
Δr_{grz}	PE range step used for calculation of grazing angles	meters	APMINIT CSC
Δr_{PE}	PE range step	meters	PEINIT SU
Δr_{PE2}	½ PE range step	meters	PEINIT SU
f_{ter}	Logical flag indicating if terrain profile has been specified: '.true.' = terrain profile specified '.false.' = terrain profile not specified	N/A	APMINIT CSC
$hmref$	Height relative to h_{minter}	meters	TERINIT SU
$ihybrid$	Integer indicating which sub-models will be used: 0 = FEDR + PE model 1 = full hybrid model (PE + FE + RO + XO) 2 = partial hybrid model (PE + XO)	N/A	APMINIT CSC
i_{gPE}	Number of grazing angles computed from spectral estimation	N/A	GETANGLES SU
i_{grz}	Number of grazing angles computed from ray trace	N/A	GETANGLES SU
i_{PE}	Number of PE range steps	N/A	PEINIT SU
l_{duct}	Logical flag indicating if surface-based duct profile has been specified '.true'. = surface-based duct exists '.false.' = no surface-based duct exists	N/A	REFINIT SU
l_{evap}	Logical flag indicating if evaporation duct profile has been specified '.true'. = evaporation duct exists '.false.' = no evaporation duct exists	N/A	REFINIT SU
l_{spec}	Logical flag indicating if grazing angles need to be computed via spectral estimation. '.true.' = compute grazing angles by spectral estimation '.false.' = do not compute grazing angles by spectral estimation	N/A	GETANGLES SU
ψ_{PE}	Array containing grazing angles computed from spectral estimation of PE field	radians	GETANGLES SU
ψ_{ray}	Two-dimensional array containing grazing angles and corresponding ranges r_{ray} computed from ray trace	radians, meters	GETANGLES SU
r_{flat}	Maximum range at which the terrain profile remains flat from the source	meters	Calling SU
r_{hor}	Radio horizon range	meters	PEINIT SU
r_{max}	Maximum output range	meters	Calling CSCI
y_{fref}	Ground elevation height at the source	meters	APMINIT CSC

Table 39. GRAZE_INT SU output data element requirements.

Name	Description	Units
i_{error}	Integer variable indicating error number for ALLOCATE and DEALLOCATE statements	N/A
Ψ	Array of interpolated grazing angles at each PE range step	radians

5.1.17 Height Check (HTCHECK) SU

The HTCHECK SU checks to see if the current traced height is below the current ground height. If so, the SU will calculate the reflection point and return with the modified angle, range, and height of the reflection point.

Upon entering the SU the following in-line functions are defined:

$$\mathbf{AP}(a,b) = a + b g_{rd}$$
$$\mathbf{HP}(a,b,c) = a + \frac{b^2 - c^2}{2 g_{rd}}.$$

Next, the current terrain height is determined according to

$$h_{ter} = ty_i + (r - tx_i) slp_i$$

where i is the terrain segment at the current range. If the current traced ray height, h_1, is greater than h_{ter}, then nothing is done and the SU is exited. Otherwise, the SU proceeds with the following steps.

a. If the current angle (a_1) is less than zero, and both the current traced ray height (h_1) and h_{ter} are less than ht_{lvl}, then nothing is done and the SU is exited.

b. At this point h_1 is less than h_{ter} and appears to have a valid reflection point. Therefore, the range at which this occurs is then computed based on solving a quadratic.

$$ra = b^2 - 4 g_{rd} c ,$$
$$b = 2(a_0 - slp_i - g_{rd} r_0),$$
$$c = g_{rd} r_0^2 - 2 a_0 r_0 - 2(ty_i - h_0) + 2 slp_i tx_i .$$

If ra is greater than 0, then two possible range values are determined in step 3. Otherwise, the SU proceeds to step 4.

c. The two range points are determined according to

$$rx_1 = \frac{-b + \sqrt{ra}}{2g_{rd}}; \quad rx_2 = \frac{-b - \sqrt{ra}}{2g_{rd}}.$$

The two range values are then compared with the previous and current range values r_0 and r_1 for valid ranges between these two points. One valid range is then selected and r_1 is set to this value. If no valid range is determined, then the SU exits with an i_{error} value of -100. **If this occurs, please see the APM developers.**

d. A new angle and height of the traced ray is then determined as

$$a_1 = \mathbf{AP}(a_0, r_1 - r_0); \qquad \textit{for } a_0 < 10°$$
$$h_1 = \mathbf{HP}(h_0, a_1, a_0),$$

or

$$a_1 = a_0$$
$$h_1 = h_0 + (r_1 - r_0)\mathbf{TAN}^{-1}(a_1) - \frac{(r_1 - r_0)^2}{twoka}, \quad \textit{for } a_0 \geq 10°,$$

and the SU is then exited.

Table 40 and Table 41 provide identification, description, units of measure, and the computational source for each HTCHECK SU input and output data element.

Table 40. HTCHECK SU input data element requirements.

Name	Description	Units	Source
a_0	Starting angle of ray trace step	radians	RGTRACE SU
a_1	Ending angle of ray trace step	meters	RGTRACE SU
g_{rd}	Gradient at current ray trace step	M-units/ meter	RGTRACE SU
h_0	Starting height of ray trace step	meters	RGTRACE SU
h_1	Ending height of ray trace step	meters	RGTRACE SU
ht_{lvl}	Height of the upper refractivity level within the current layer	meters	RGTRACE SU
it	Index of the current terrain segment in arrays *tx* and *ty*	N/A	RGTRACE SU
r_0	Starting range of ray trace step	meters	RGTRACE SU

Table 40. HTCHECK SU input data element requirements. (continued)

Name	Description	Units	Source
slp	Slope of the terrain segment at the current range.	N/A	TERINIT SU
twoka	Twice the effective earth radius	meters	GET_K SU
tx	Range points of terrain profile	meters	TERINIT SU
ty	Height points of terrain profile	meters	TERINIT SU

Table 41. HTCHECK SU output data element requirements.

Name	Description	Units
i_{error}	Integer variable indicating error number for ALLOCATE and DEALLOCATE statements	N/A
a_1	Ending angle of ray trace step	meters
h_1	Ending height of ray trace step	meters
ihit	Integer flag indicating if ray has hit surface: *ihit* = 0; ray has not hit the surface *ihit* =1; ray has hit the surface	N/A
r_1	Ending range of ray trace step	meters

5.1.18 Interpolate Profile (INTPROF) SU

The INTPROF SU performs a linear interpolation vertically with height on the refractivity profile, *refref*. Interpolation is performed at each PE mesh height point.

To interpolate vertically at each PE mesh height, the following iteration is performed. The index j is determined such that for every i^{th} PE bin, ht_i is just greater than $href_j$ and $j < nlvl$. The interpolated profile *profint* is then determined from

$$profint_i = refref_{j-1} + con\left(refref_j - refref_{j-1}\right)\frac{ht_i - href_{j-1}}{href_j - href_{j-1}}; \quad i = 1,2,3,\ldots n_{fft},$$

where the array *ht* and constant *con* have been determined in the APMINIT CSC.

Table 42 and Table 43 provide identification, description, units of measure, and the computational source for each INTPROF SU input and output data element.

Table 42. INTPROF SU input data element requirements.

Name	Description	Units	Source
con	$10^{-6}k_o$	meters^{-1}	APMINIT CSC
href	Heights of refractivity profile with respect to local ground height	meters	PROFREF SU
ht	PE mesh height array of size n_{fft}	meters	PEINIT SU
n_{fft}	Transform size	N/A	FFTPAR SU
nlvl	Number of levels in new profile	N/A	PROFREF SU
refref	Refractivity array	M-units	PROFREF SU

Table 43. INTPROF SU output data element requirements.

Name	Description	Units
profint	Profile interpolated to every Δz_{PE} in height	M-units

5.1.19 PE Initialization (PEINIT) SU

The PEINIT SU initializes all variables used in the PE model for subsequent calls to the PESTEP SU.

Upon entering the SU several variables are initialized. The following PE transform variables are computed – the angle (or p-space) mesh size, Δp; the Fourier transform normalization constant, f_{norm}; the angle bin width, $\Delta\theta$, and various transform size factors:

$$\Delta p = \frac{\pi}{z_{max}}, \quad f_{norm} = \frac{2}{n_{fft}}, \quad n_{34} = \tfrac{3}{4} n_{fft},$$

$$\Delta\theta = \frac{\Delta p}{k_o}, \qquad n_{m1} = n_{fft} - 1, \quad n_4 = \tfrac{1}{4} n_{fft},$$

The ALLARRAY_PE SU is then referenced to allocate and initialize all arrays associated with PE calculations.

Next, the horizon range, r_{hor}, for 0 receiver height and the tangent angle, a_{cut}, to the radio horizon are computed:

$$r_{hor} = \sqrt{twoka * ant_{ht}}$$

$$a_{cut} = \mathbf{TAN}^{-1}\left(\frac{ant_{ht}}{r_{hor}}\right).$$

A temporary range step variable is computed as

$$\Delta rt = 55.67485 + 3.52969 \times 10^{-3} r_{max} - .01122 \times 10^{-6} r_{max}^2 .$$

Due to numerical constraints, limits will be imposed on the PE range step as follows. If performing a terrain case, then the PE range step is computed from

$$\Delta r_{PE} = \mathbf{MAX}\left(\mathbf{MIN}\left(2k_o \Delta z_{PE}^2, 700.\right), \Delta rt\right).$$

If r_{fix} (previously determined in the TERINIT SU) is greater than 0, then the temporary range step variable r_d is given by $r_d = \dfrac{r_{fix}}{\Delta r_{PE}}$ and Δr_{PE} is recomputed according to

$$\Delta r_{PE} = \mathbf{NINT}\left(\frac{1}{r_d}\right) r_{fix}; \text{ for } r_d < 1,$$

$$\Delta r_{PE} = \frac{r_{fix}}{\mathbf{NINT}\left(r_d\right)}; \text{ for } r_d \geq 1.$$

The variable iz_{inc} is then initialized to 1.

If no terrain profile is specified, then Δr_{PE} is given by

$$\Delta r_{PE} = \mathbf{MAX}\left(2k_o \Delta z_{PE}^2, \Delta rt, 100.\right),$$

with the variable iz_{inc} initialized to 1 for frequencies greater than 10 GHz, 2 for frequencies greater than 5 GHz, and 3, otherwise.

If the PEINIT SU has been referenced from the GET SU, then the PE range step (which in this case will be used for calculation of the grazing angle by spectral estimation) is further modified:

$$\Delta r_{PE} = \mathbf{MAX}\left(\Delta r_{PE}, 150.\right) - 1 .$$

Otherwise, the range step is multiplied by the range step modifier r_{mult}.

The number of PE range steps is then computed:

$$i_{PE} = \mathbf{NINT}\left(\frac{r_{max}}{\Delta r_{PE}}\right) + 1 .$$

If a terrain profile has been specified, the terrain elevations at each PE range step are now interpolated from the user-specified profile and stored in array *tyh*. The array is allocated for size i_{PE}, the range r is initialized to 0, and the elements in *tyh* are determined according to

$$tyh_i = ty_k + slp_k\left(r - tx_k\right); \quad i = 1, 2, ..., i_{PE} ,$$

where r is $i\Delta r_{PE}$ and the index k is determined such that $tx_k < r \le tx_{k+1}$. The tangent of each angle determined from the terrain slopes are stored in array *tang*.

The filter array, *filt*, for subsequent filtering of the PE field, is given by

$$filt_i = \tfrac{1}{2} + \tfrac{1}{2}\mathbf{COS}\left(i\frac{\pi}{n_4}\right); \quad i = 1, 2, ..., n_4$$

The PE mesh height array *ht* is next given by

$$ht_i = i\,\Delta z_{PE}; \quad i = 1, 2, ..., n_{fft} ,$$

Next, the free-space propagator array *frsp* is computed for subsequent use in the PESTEP SU. The propagator term is computed at each PE angle, or p-space, mesh point using the wide-angle propagator. A filter, or attenuation function (frequently called “window”), is then applied to the upper one-quarter of the array corresponding to the highest one-quarter of the maximum propagation angle.

The complex free-space propagator phase array *frsp* is given by

$$frsp_j = f_{norm} e^{i\Delta r_{PE}\left(\sqrt{k_o^2 - (j\Delta p)^2} - k_o\right)}; \qquad j = 0,1,2,..., n_{fft} ,$$

where I is the imaginary number $\sqrt{-1}$. The upper one-quarter of the free-space propagator array is filtered by a cosine-tapered (Tukey) filter array, *filt*, according to

$$frsp_j = filt_{j-n_{34}}\, frsp_j; \quad j = n_{34}, n_{34}+1, n_{34}+2, ..., n_{fft} .$$

If a simple environmental case has been specified with no terrain and a range-independent refractivity profile, then the INTPROF SU is referenced for interpolation of the refractivity at every PE mesh point. The z-space propagator array *envpr* is then computed from

$$envpr_j = e^{i\Delta r_{PE}\, profint_j}; \qquad j = 0, 1, 2, ..., n_{fft},$$

where *I* is the imaginary number $\sqrt{-1}$ and *profint* is the sampled profile obtained from the INTPROF SU. The upper ¼ of *envpr* is filtered by a cosine-tapered (Tukey) filter array, *filt*, according to

$$envpr_j = filt_{j-n_{34}}\, envpr_j;\ \ for\ j = n_{34}, n_{34}+1, n_{34}+2, ..., n_{fft}\ .$$

Finally, the XYINIT SU is referenced to determine the initial PE solution and the SU is exited.

Table 44 and Table 45 provide identification, description, units of measure, and the computational source for each PEINIT SU input and output data element.

Table 44. PEINIT SU input data element requirements.

Name	Description	Units	Source
ant_{ht}	Transmitting antenna height above local ground	meters	Calling CSCI
Δz_{PE}	Bin width in z-space	meters	FFTPAR SU
f_{MHz}	Frequency	MHz	Calling CSCI
f_{ter}	Logical flag indicating if terrain profile has been specified: ‘.true.’ = terrain profile specified ‘.false.’ = terrain profile not specified	N/A	APMINIT CSC
i_{flag}	Integer flag indicating where in the APMINIT CSC the PEINIT SU is being referenced 0 = called before reference to GETANGLES SU 1 = called for “real” PE run	N/A	Calling SU
i_{pl}	Polarization flag 0 = horizontal 1 = vertical	N/A	Calling SU
i_{tpa}	Number of height/range points pairs in terrain profile arrays *tx*, *ty*	N/A	TERINIT SU
k_o	Free-space wavenumber	meters^{-1}	APMINIT CSC
n_{fft}	Transform size	N/A	FFTPAR SU
n_{prof}	Number of refractivity profiles	N/A	Calling CSCI

Table 44. PEINIT SU input data element requirements. (continued)

Name	Description	Units	Source
PE_{flag}	Flag to indicate use of PE algorithm only: '.true.' = only use PE sub-model '.false.' = use automatic hybrid model	N/A	Calling CSCI
r_{fix}	Fixed range increment of terrain profile	meters	Calling SU
r_{max}	Maximum specified range	meters	Calling CSCI
r_{mult}	PE range step multiplication factor	N/A	Calling CSCI
slp	Slope of each segment of terrain	N/A	TERINIT SU
$twoka$	Twice the effective earth radius	meters	GET_K SU
tx	Range points of terrain profile	meters	TERINIT SU
ty	Adjusted height points of terrain profile	meters	TERINIT SU
z_{max}	Total height of the FFT/PE calculation domain	meters	FFTPAR SU

Table 45. PEINIT SU output data element requirements.

Name	Description	Units
a_{cut}	Tangent angle from antenna height to radio horizon	radians
Δr_{PE}	PE range step	meters
Δp	P-space mesh size	radians/ meters
$\Delta\theta$	Angle bin width	radians
$envpr$	Complex [refractivity] phase term array interpolated every Δz_{PE} in height	N/A
$filt$	Cosine-tapered (Tukey) filter array	N/A
f_{norm}	Normalization factor	N/A
$frsp$	Complex free space propagator term array	N/A
ht	PE mesh height array of size n_{fft}	meters
i_{error}	Integer variable indicating error number for ALLOCATE and DEALLOCATE statements	N/A
i_{PE}	Number of PE range steps	N/A
iz_{inc}	Integer increment for storing points at top of PE region (i.e., points are stored at every iz_{inc} range step)	N/A
n_{34}	¾ n_{fft}	N/A
n_4	¼ n_{fft}	N/A
n_{m1}	n_{fft} -1	N/A
r_{hor}	Radio horizon range	meters
$tang$	Tangent of angle array from terrain slopes.	radians
tyh	Adjusted height points of terrain profile at every PE range step.	meters
U	Complex PE field	µV/m

5.1.20 Poly 4 (FN_POLY4) Function

The real, double precision function FN_POLY4 evaluates a 4th order polynomial in the independent variable, *X*, for the SURFIMP SU. It returns the real (imaginary) part of the complex normalized surface impedance to the SURFIMP SU. The expression evaluated is

$$fx = const4_5 X^4 + const4_4 X^3 + const4_3 X^2 + const4_2 X + const4_1 .$$

Variables passed to the POLY4 function by the SURFIMP SU are the frequency in megahertz and the array of five coefficients needed to evaluate the polynomial.

Table 46 and Table 47 provide identification, description, units of measure, and the computational source for each FN_POLY4 function input and output data element.

Table 46. FN_POLY4 input data element requirements.

Name	Description	Units	Source
const4	Polynomial coefficients array	See a	Calling SU
X	Independent variable (frequency)	MHz	Calling SU

[a] $1/(MHz)^{n-1}$ where n=1,2,3,4,5

Table 47. FN_POLY4 output data element requirements.

Name	Description	Units
fx	Real (imaginary) part of normalized surface impedance	N/A

5.1.21 Poly 5 (FN_POLY5) Function

The real, double-precision function FN_POLY5 evaluates a 5th order polynomial in the independent variable, *X*, for the SURFIMP SU. Each call of the routine returns one element of the array *const4*, which is used in the FN_POLY4 SU. The expression evaluated is

$$fx = const5_6 X^5 + const5_5 X^4 + const5_4 X^3 + const5_3 X^2 + const5_2 X + const5_1 .$$

Variables passed to the FN_POLY5 function by the SURFIMP SU are the wind speed in knots and the set of six polynomial coefficients needed to evaluate the polynomial.

Table 48 and Table 49 provide identification, description, units of measure, and the computational source for each FN_POLY5 function input and output data element.

Table 48. FN_POLY5 input data element requirements.

Name	Description	Units	Source
*const*5	Polynomial coefficients array	See a	Calling SU
X	Independent variable (wind speed)	knots	Calling SU

[a] $1/(\text{MHz})^{n-1}(\text{knots})^{n-1}$ where n=1,2,3,4,5,6

Table 49. FN_POLY5 output data element requirements.

Name	Description	Units
fx	Element of the array *const4*	See a

[a] $1/(\text{MHz})^{n-1}$ where n=1,2,3,4 or 5

5.1.22 Profile Reference (PROFREF) SU

The PROFREF SU adjusts the current refractivity profile so that it is relative to a reference height, y_{ref}. The reference height is initially the minimum height of the terrain profile. Upon subsequent calls from the PESTEP SU, the refractivity profile is adjusted by the local ground height at each PE range step.

The reference height y_{ref}, depending on the value of i_{flag}, can be h_{minter} or the local ground height above h_{minter}. If i_{flag} is 0, the profile arrays *refref* and *href* will be relative to h_{minter} and will also be used to initialize *refdum* and *htdum* . If $\boxed{}$ is 1, then the profile arrays *refref* and *href* will be referenced to the local ground height. The parameter h_{minter} is the reference height for internal calculations in the APM CSCI of the complex field *U*. Arrays *refdum* and *htdum* are dummy arrays containing refractivity values and height values, respectively, for the currently interpolated profile.

Determining *refref* and *href* proceeds as follows. First, the index *nlvl* is initialized to the number of refractivity levels, *lvlep*, in *refdum* and *htdum;* and *refref* and *href* are initialized to zero. Next, a test is made to determine whether the absolute value of the reference height y_{ref} is greater than 10^{-3} (i.e., is y_{ref} greater than approximately 0). If y_{ref} is approximately zero, the elements of *refref* are set equal to the corresponding M-unit values of *refdum*, and the elements of *href* are set equal to the corresponding height values of *htdum* and the SU is exited.

For the case when y_{ref} is not zero, the following calculations are made. First, the flag i_{bmsl} and the index j_s are set equal to zero and minus one, respectively. Then, y_{ref} is tested to determine if it is below mean sea level. If so, i_{bmsl} and *j* are set equal to one and zero, respectively. If y_{ref} is not below mean sea level, then the refractivity profile level at which y_{ref} is just above is determined. The index *j* is determined such that $htdum_j < y_{ref} \leq htdum_{j+1}$.

The refractivity at y_{ref} is now computed from

$$rmu = refdum_j + \left(refdum_{j+1} - refdum_j\right)\frac{y_{ref} - htdum}{htdum_{j+1} - htdum_j} .$$

If y_{ref} falls below mean sea level and the extrapolation flag i_{extra} is zero, then *rmu* is given by

$$rmu = refdum_j + 0.118\frac{y_{ref} - htdum_j}{htdum_{j+1} - htdum_j} .$$

The first element in *refref* and *href* is now set equal to *rmu* and 0, respectively. The number of refractivity levels in the arrays is now $l_{new} = nlvl - j$ and the remainder of the current refractivity profile is adjusted in height and stored in *refref* and *href* according to

$$refref_i = refdum_k$$
$$href_i = htdum_k - y_{ref}; \quad i = 1, 2, 3, ..., l_{new},$$

where the index *k* is initialized to *j*+1 and is incremented by one with each iteration of *i*. The variable *nlvl*, indicating the number of levels in the newly created profile, is now set to l_{new}.

Finaly, if i_{flag} equals zero, then *lvlep* is set equal to *nlvl* and *refref* and *href* are used to initialize *refdum* and *htdum*, respectively, before exiting.

Table 50 and Table 51 provide identification, description, units of measure, and the computational source for each PROFREF SU input and output data element.

Table 50. PROFREF SU input data element requirements.

Name	Description	Units	Source
htdum	Height array for current interpolated profile	meters	REFINTER SU
i_{extra}	Extrapolation flag for refractivity profiles entered below mean sea level 0 = extrapolate to minimum terrain height standard atmosphere gradient 1 = extrapolate to minimum terrain height using first gradient in profile	N/A	Calling CSCI

Table 50. PROFREF SU input data element requirements. (continued)

Name	Description	Units	Source
i_{flag}	Integer flag indicating height at which to reference the refractivity profile 0 = adjust profile relative to h_{minter} 1 = adjust profile relative to local ground height above h_{minter}	N/A	Calling SU
lvlep	Number of height/refractivity levels in profile *refdum* and *htdum*	N/A	Calling CSCI
refdum	M-unit array for current interpolated profile	M-units	REFINTER
y_{ref}	Ground elevation height at current range	meters	Calling SU

Table 51. PROFREF SU output data element requirements.

Name	Description	Units
href	Height array for current interpolated profile	meters
htdum	Dummy array containing height values for current (horizontally interpolated) profile	meters
lvlep	Number of height/refractivity levels in profile	N/A
nlvl	Number of levels in new profile	N/A
refdum	M-unit array for current interpolated profile	M-units
refref	Refractivity array	M-units

5.1.23 Refractivity Initialization (REFINIT) SU

The REFINIT SU checks for valid environmental profile inputs and initializes all refractivity arrays used within one application of APM.

Upon entering, the maximum height h_{large} at which the refractivity profile is extrapolated is set to 10^6 meters in a DATA statement. In addition, i_{error} is initialized to zero.

The environmental data are checked to determine if range-dependent profiles have been specified (n_{prof} >1). If so, the range of the last profile entered, $rngprof_{n_{prof}}$, is checked, and if it is less than the maximum output range specified, r_{max} , an error message is returned (i.e., i_{error} is set equal to -12) depending on the value of the error flag, *lerr*12, set in the calling CSCI application itself. The SU is then exited; otherwise, if no error occurs, the SU proceeds to the next step.

Next, the REFINIT SU tests for valid refractivity level entries for each profile. Every user-specified profile is tested to make sure the first level in the profile begins with a value of zero height (or less than zero, if the first level is below mean sea level). If it does not, i_{error} is set to -13 and the SU is exited; otherwise, the SU proceeds to the next step.

A test is then made to determine if the last gradient in each profile is negative. If the last gradient in any profile is negative, i_{error} is set to -14 and the SU is exited; otherwise, an additional refractivity level is extrapolated to height h_{large} and added to each profile. The additional level is added according to

$$\left.\begin{aligned} hmsl_{lvlp,i} &= h_{large}, \\ refmsl_{lvlp,i} &= refmsl_{lvlp-1,i} + grd\left[h_{large} - hmsl_{lvlp-1,i}\right] \end{aligned}\right\} \quad i = 1, 2, 3, \ldots n_{prof} \quad ,$$

where

$$grd = \frac{refmsl_{lvlp-1,i} - refmsl_{lvlp-2,i}}{hmsl_{lvlp-1,i} - hmsl_{lvlp-2,i}} \ .$$

The counter for the current profile, i_s, is now initialized to 1 and the range of the next refractivity profile, rv_2, is initialized to $rngprof_{i_s}$. Next, the results of the extrapolation of the first environmental profile (i.e., the profile at range 0) are transferred to dummy arrays, *htdum* and *refdum*, respectively. The index *lvlep* is now set equal to *lvlp*. Duplicate levels in the first profile are removed by a reference to the REMDUP SU, and *refdum* and *htdum* are adjusted to the minimum terrain height by a reference to the PROFREF SU. The parameter *nlvl*, returned from the PROFREF SU, is now the number of height/refractivity levels in the adjusted *htdum* and *refdum* arrays.

If troposcatter calculations have been specified (T_{ropo} = '.true.'), then the surface refractivity at the transmitter $snref_{tx}$ is determined by referencing the PROFREF SU to adjust the profile relative to y_{fref} and initializing $snref_{tx}$ to $refref_0$.

Next, the height and thickness of the highest trapping layer (if one exists), h_{trap} and h_{thick}, respectively, are found relative to h_{minter}. First, h_{trap} and h_{thick} are initialized to zero. Then, steps 1 through 2 are performed for each i^{th} profile and for each j^{th} refractivity level.

1. The gradient of the current height/refractivity level *grd* and its height relative to h_{minter}, h_{p1}, are found from

$$\begin{aligned} grd &= refmsl_{j+1,i} - refmsl_{j,i} \\ h_{p1} &= hmsl_{j+1,i} - h_{minter} \qquad . \end{aligned}$$

2. If grd is negative and h_{p1} is greater than h_{trap}, then h_{trap} is set equal to h_{p1}, and h_{p0} and h_{thick} are determined from

$$h_{p0} = hmsl_{j,i} - h_{minter}$$
$$h_{thick} = h_{p1} - h_{p0}$$

Next, the index level i_{start1} within the refractivity profile of the antenna height ant_{ref} is determined and the gradient array $grdum$ is computed as

$$grdum_i = 10^{-6}\left(\frac{refdum_{i+1} - refdum_i}{htdum_{i+1} - htdum_i}\right); \quad i = 0, 1, 2, ..., lvlep - 1.$$

If using the full hybrid mode (i_{hybrid} = 1), then follow steps 1 through 4 to build arrays associated with RO calculations. Otherwise, the M-unit value rm_{tx} at the antenna height is determined from

$$rm_{tx} = 10^{-6}\left[refdum_{i_{start1}} + grdum_{i_{start1}} 10^{6}\left(ant_{ref} - htdum_{i_{start1}}\right)\right]$$

and the SU continues with the procedures after step 4.

1. First, the refractivity and height arrays rm and zrt are built. All elements in zrt are set equal to all elements in $htdum$. An additional height level, equal to ant_{ref}, is included in zrt and the index i_{start} is initialized to that height level that corresponds to ant_{ref}. Array rm is given by

$$rm_i = 10^{-6} refdum_i, \qquad i = 1, 2, 3, ..., nlvl,$$

with the refractivity level at height ant_{ref} interpolated according to

$$rm_{i_{start}} = rm_{i_{start}+1} + \left(ant_{ref} - zrt_{i_{start}-1}\right)\left(\frac{rm_{i_{start}+1} - rm_{i_{start}-1}}{zrt_{i_{start}+1} - zrt_{i_{start}-1}}\right).$$

The total number of levels $levels$ in zrt is reduced by 1 since the highest level is not needed.

2. For the special case when the terrain profile is initially flat but at non-zero height, perform steps 2.a through 2.d to adjust the refractivity arrays rm and zrt associated with RO calculations. First, the index $nlevel$ is initialized to the number of refractivity

levels, *levels*; y_{ref} is initialized to ty_1; *refref* and *href* are initialized to zero; and the index *js* is initialized to -1.

a. Next, *js* is determined such that $zrt_{js} < y_{ref} \le zrt_{js+1}$. If a value for *js* is not found such that this condition holds true (i.e., *js* remains at -1), then the SU proceeds with step 2.d.

b. The refractivity at y_{ref} is now computed from

$$f_{rac} = \frac{y_{ref} - zrt_{js}}{zrt_{js+1} - zrt_{js}},$$

$$rmu = rm_{js} + f_{rac}\left(rm_{js+1} - rm_{js}\right).$$

If INT(f_{rac}) is equal to 1, then *js* is set equal to *js*+1. The temporary counter l_{new} is initialized to *nlevel-js*.

c. The first element in *refref* and *href* is now set equal to *rmu* and 0, respectively. The remainder of the current refractivity profile is adjusted in height and stored in *refref* and *href* according to

$$\begin{aligned} refref_j &= rm_k \\ href_j &= zrt_k - y_{ref}; \quad j = 1,2,3,\ldots l_{new}, \end{aligned}$$

where the index *k* is initialized to *js*+1 at the start and is incremented by one with each iteration of *j*. The variable *levels*, indicating the number of levels in the newly created profile, is now set to l_{new}. *refref* and *href* are now used to initialize *rm* and *zrt*.

d. The variable i_{start} is now reduced by the amount *js*.

3. The arrays *gr* and *q*, used in RO and ray-tracing calculations, are determined next. The gradient array *gr* is given by

$$gr_i = \frac{rm_{i+1} - rm_i}{zrt_{i+1} - zrt_i}; \quad i = 0, 1, 2, \ldots levels,$$

The array *q* is given by

$$q_i = 2\left(rm_{i+1} - rm_i\right); \quad i = 0, 1, 2, \ldots, levels.$$

4. The M-unit value rm_{tx} at the antenna height is now set equal to $rm_{i_{start}}$.

Next, the minimum M-unit value rm_{min} of the refractivity at range 0 is determined by searching for the minimum numerical value in arrray *refdum* and assigning rm_{min} this value. The maximum M-unit value rm_{max} at or below the antenna height is then determined from

$$rm_{max} = \mathbf{MAX}\left(10^6\, rm_{tx},\ refdum_i\right), \qquad i = 0, 1, 2, \ldots, i_{start1}\,.$$

Both rm_{min} and rm_{max} are then multiplied by 10^{-6}. If the antenna is within a duct, the flag l_{duct} is set to '.true.' and the critical angle a_{crit} is computed as

$$a_{crit} = \sqrt{2\left(rm_{tx} - r_{crit}\right)} + 10^{-6},$$

where r_{crit} is the minimum M-unit value in the profile for levels above the height ant_{ref}.

Finally, a check is made to determine if an evaporation profile exists. This check is performed only if a range-independent profile has been specified (n_{prof} = 1) and if h_{trap} is greater than 0. An evaporation duct is assumed to exist if the height at which rm_{min} occurs is less than 50 m and if the second derivative of the profile is greater than an arbitrarily set 100 M-units/m^2. If these two conditions occur, then the flag l_{evap} is set to '.true.'.

Table 52 and Table 53 provide identification, description, units of measure, and the computational source for each REFINIT SU input and output data element.

Table 52. REFINIT SU input data element requirements.

Name	Description	Units	Source
ant_{ref}	Transmitting antenna height relative to the reference height h_{minter}	meters	TERINIT SU
f_{ter}	Logical flag indicating if terrain profile has been specified: '.true.' = terrain profile specified '.false.' = terrain profile not specified	N/A	APMINIT CSC
h_{minter}	Minimum height of terrain profile	meters	TERINIT SU
hmsl	Two-dimensional array containing heights with respect to mean sea level of each profile. Array format must be $hmsl_{i,j}$ = height of i^{th} level of j^{th} profile; *j*=1 for range-independent cases	meters	Calling CSCI

Table 52. REFINIT SU input data element requirements. (continued)

Name	Description	Units	Source
i_{hybrid}	Integer indicating which sub-models will be used: 0 = FEDR + PE model 1 = full hybrid model (PE + FE + RO + XO) 2 = partial hybrid model (PE + XO)	N/A	APMINIT CSC
lerr12	User-provided error flag that will trap on certain errors if set to '.true.'	N/A	Calling CSCI
lvlp	Number of height/refractivity levels in profiles	N/A	Calling CSCI
nprof	Number of refractivity profiles	N/A	Calling CSCI
refmsl	Two-dimensional array containing refractivity with respect to mean sea level of each profile. Array format must be $refmsl_{i,j}$ = M-unit at i^{th} level of j^{th} profile; j=1 for range-independent cases	M-unit	Calling CSCI
r_{max}	Maximum range	meters	Calling CSCI
rngprof	Ranges of each profile. $rngprof_i$ = range of i^{th} profile	meters	Calling CSCI
tery	Dynamically allocated terrain profile height array	meters	Calling CSCI
ty	Adjusted height points of terrain profile	meters	TERINIT SU

Table 53. REFINIT SU output data element requirements.

Name	Description	Units
a_{crit}	Critical angle	radians
gr	Intermediate M-unit gradient array, RO region	$(\text{M-unit/m})10^{-6}$
grdum	Array of refractivity gradients defined by profile *htdum* and *refdum*	M-units/meter
hmsl	Two-dimensional array containing heights with respect to mean sea level of each profile. Array format must be $hmsl_{i,j}$ = height of i^{th} level of j^{th} profile; j=1 for range-independent cases	meters
htdum	Height array for current interpolated profile	meters
h_{thick}	Thickness of highest trapping layer from all refractivity profiles	meters
h_{trap}	Height of highest trapping layer from all refractivity profiles	meters
i_{error}	Integer value that is returned if any errors exist in input data	N/A
i_s	Counter for current profile	N/A
i_{start}	RO height index at antenna height	N/A
i_{start1}	Refractivity level index within *htdum* at ant_{ref}	N/A
l_{duct}	Logical flag indicating if surface-based duct profile has been specified '.true'. = surface-based duct exists '.false.' = no surface-based duct exists	N/A
l_{evap}	Logical flag indicating if evaporation duct profile has been specified '.true'. = evaporation duct exists '.false.' = no evaporation duct exists	N/A
levels	Number of levels defined in *zrt*, *rm*, *q*, and *gr* arrays	N/A

Table 53. REFINIT SU output data element requirements. (continued)

Name	Description	Units
lvlep	Number of height/refractivity levels in profile *htdum*, *refdum*	N/A
lvlp	Number of user-specified levels in refractivity profile (for range dependent case all profiles must have same number of levels)	N/A
nlvl	Number of height/refractivity levels in profile *refref*, *href*	N/A
q	Intermediate M-unit difference array, RO region	M-unit 10^{-6}
refdum	M-unit array for current profile	M-unit
refmsl	Two-dimensional array containing refractivity with respect to mean sea level of each profile. Array format must be $refmsl_{i,j}$ = M-unit at i^{th} level of j^{th} profile; *j*=1 for range-independent cases	M-unit
rm	Intermediate M-unit array, RO region	M-unit 10^{-6}
rm_{max}	Maximum M-unit value of refractivity profile at range 0	meters
rm_{min}	Minimum M-unit value of refractivity profile at range 0	meters
rm_{tx}	M-unit value at height ant_{ref}	meters
rv2	Range of the next refractivity profile	meters
$snref_{tx}$	Surface refractivity at transmitter	M-unit
$snref_0$	Surface refractivity taken from of the reference profile with respect to mean sea level	M-unit
zrt	Intermediate height array, RO region	meters

5.1.24 Remove Duplicate Refractivity Levels (REMDUP) SU

The REMDUP SU is to remove any duplicate refractivity levels in the current interpolated profile. Adjoining profile levels are checked to see if the heights are within 0.001 m. If they are, the duplicate level in the profile is removed. This process continues until all profile levels (*lvlep*) have been checked.

Table 54 and Table 55 provide identification, description, units of measure, and the computational source for each REMDUP SU input and output data element.

Table 54. REMDUP SU input data element requirements.

Name	Description	Units	Source
htdum	Height array for current interpolated profile	meters	REFINIT SU REFINTER SU
lvlep	Number of height/refractivity levels in profile	N/A	REFINIT SU REFINTER SU
refdum	M-unit array for current interpolated profile	M-unit	REFINIT SU REFINTER SU

Table 55. REMDUP SU output data element requirements.

Name	Description	Units
htdum	Height array for current interpolated profile	meters
lvlep	Number of height/refractivity levels in profile	N/A
refdum	M-unit array for current interpolated profile	M-unit

5.1.25 RG Trace (RGTRACE) SU

The RGTRACE SU performs ray traces of many rays launched within an angle of ±4°. All angles from rays striking the surface are then sorted and stored for subsequent interpolation in the GRAZE_INT SU.

Upon entering the SU, two in-line ray trace functions are defined for general parameters *a*, *b*, and g_{rd}: RADA1 and RP. These function definitions are identical to those given in Section 5.1.15.

Rays are traced with different angular increments at varying intervals. Angular increments are determined such that 1500 rays will be traced between the angular interval ±0.5°, 1000 rays will be traced with launch angles between $|0.5°|$ and $|\theta_t|$, and 500 rays will be traced for angles between $|\theta_t|$ and $|\vartheta_{mxg}|$. The angular increments are computed as

$$ainc_1 = \frac{\theta_t}{1500},$$
$$ainc_2 = \frac{\theta_t}{500},$$
$$ainc_3 = \frac{\vartheta_{mxg} - \theta_t}{250},$$

where θ_t is 1° for i_{hybrid} equal to 1 and 1.5°, otherwise. The maximum number of rays to trace, n_{ray}, is then initialized to a large value of 10 times the amount specifed above.

Next, the grazing angle array ψ_{ray} is allocated and initialized with the first element set equal to ½π. The height of the terrain y_t at the current traced range step is initialized to 0, or tyh_1 if a terrain profile has been specified (f_{ter}='.true.'). The number of grazing angles i_{grz} and the launch angle a_{launch} are initialized to 0 and $-\vartheta_{mxg}$, respectively. A DO loop is now implemented where the following steps 1 through 4 are performed an n_{ray} number of times.

1. At the start of the ray trace, the current local angle (a_0), range (r_0), height (h_0), and refractive gradient index (*j*) are initialized to a_{launch}, 0, ant_{ref}, and i_{start1}, respectively. The index, *it*, of the terrain segment at the current traced range is also initialized to 1.

2. If the antenna height ant_{ref} is at an inflection point in the refractivity profile and a_0 is less than 0, the index j is decremented by 1. The current range to trace to, ro, is initialized to 0.

3. A loop is now begun to trace a ray starting with launch angle a_{launch} to every PE range step. The current range to trace to, ro, is incremented by Δr_{PE} and steps 0 through 3.e are performed until one of the following conditions are met: r_0 reaches ro, h_0 reaches ht_{lim}, or the difference in reflection range between consecutive grazing angles is less than 10^{-3}. All references to the index i in the steps below refer to the index in this loop varying from 1 to the number of PE range steps, i_{PE}.

   a. The TRACE_STEP SU is referenced to determine the new angle (a_1), height (h_1), and range (r_1) at the end of the traced step.

   b. Once r_1, h_1, and a_1 have been computed, it must be determined if h_1 is above the height maximum ht_{lim}. If so, then h_1 is set equal to ht_{lim} and a new a_1 and r_1 are computed:

$$a_1 = \sqrt{\mathrm{RADA1}(a_0, h_1 - h_0)}$$
$$r_1 = \mathrm{RP}(r_0, a_1 - a_0).$$

   c. If the ray has hit the surface and is reflected, which would be the condition for which the index j is equal to 0, then the grazing angle and the angle of reflection with respect to the horizontal are computed as

$$\psi = \mathrm{TAN}^{-1}(slp_{it}) - a_1$$
$$a_{ref} = 2\,\mathrm{TAN}^{-1}(slp_{it}) - a_1 .$$

   The range r_1 and grazing angle are then stored for later use in the GRAZE_INT SU.

   d. In preparation for the next ray trace step, h_0 is set equal to h_1, r_0 is set equal to r_1, and a_0 is set equal to a_{ref}. If a_0 is greater than ½π, or if r_1 has reached ro, then the current iteration is exited and the SU proceeds to step 3.e; otherwise, steps 0 through 3.d are repeated until r_0 reaches ro.

   e. The range ro [to trace to] for the next step is incremented by Δr_{PE} and step 3 is repeated for all range steps.

4. Once a ray has been traced through the entire i_{PE} number of range steps, a_{launch} is increased. If $|a_{launch}|$ is less than 0.5°, the launch angle is increased by $ainc_1$;

otherwise, if $|a_{launch}|$ is less than θ_t, then it is increased by $ainc_2$. If neither of these conditions are met, then a_{launch} is increased by $ainc_3$. Steps 1 through 4 are repeated until an n_{ray} number of rays have been traced.

Finally, the grazing angles are sorted by range and stored in array ψ_{ray} and the SU is exited.

Table 56 and Table 57 provide identification, description, units of measure, and the computational source for each RGTRACE SU input and output data element.

Table 56. RGTRACE SU input data element requirements.

Name	Description	Units	Source
ant_{ref}	Transmitting antenna height relative to the reference height h_{minter}	meters	TERINIT SU
Δr_{PE}	PE range step	meters	PEINIT SU
f_{ter}	Logical flag indicating if terrain profile has been specified: '.true.' = terrain profile specified '.false.' = terrain profile not specified	N/A	APMINIT CSC
$grdum$	Array of refractivity gradients defined by profile $htdum$ and $refdum$	M-units/ meter	REFINTER SU
h_{max}	Maximum output height with respect to mean sea level	meters	Calling CSCI
$htdum$	Height array for current interpolated profile	meters	REFINTER SU
ht_{lim}	User-supplied maximum height relative to h_{minter}, i.e., $ht_{lim} = h_{max} - h_{minter}$	meters	TERINIT SU
i_{hybrid}	Integer indicating which sub-models will be used: 0 = FEDR + PE model 1 = full hybrid model (PE + FE + RO + XO) 2 = partial hybrid model (PE + XO)	N/A	APMINIT CSC
i_{start1}	Refractivity level index within $htdum$ at ant_{ref}	N/A	REFINIT SU
r_{max}	Maximum output range	meters	Calling CSCI
ϑ_{mxg}	Maximum PE calculation angle for spectral estimation of grazing angles	radians	APMINIT CSC
slp	Slope of each segment of terrain	N/A	TERINIT SU
tx	Range points of terrain profile	meters	TERINIT SU

Table 57. RGTRACE SU output data elements requirements.

Name	Description	Units
i_{grz}	Number of grazing angles computed from ray trace	N/A
ψ_{ray}	Two-dimensional array containing grazing angles and corresponding ranges computed from ray trace	radians, meters

5.1.26 Terrain Initialization (TERINIT) SU

The TERINIT SU examines and initializes terrain arrays for subsequent use in PE calculations. It tests for and determines a range increment if it is found that range/height points are provided in fixed range increments. The minimum terrain height is determined, and the entire terrain profile is adjusted in height so that all internal calculations are referenced to this height. This is done to maximize the PE transform calculation volume.

First, several variables are initialized. The integer flag, i_{error}, which is returned if any errors exist in input data, is set equal to zero. The maximum tangent ray angle, α_u, from source to terrain peak along the profile path, is set equal to zero. The minimum height of the terrain profile, h_{minter}, is set equal to zero. The transmitting antenna height, ant_{ref}, relative to the reference height h_{minter}, is set equal to ant_{ht}. The maximum terrain height, h_{termax}, along the profile path, is set equal to zero.

If performing a terrain case (f_{ter} = '.true.'), perform steps 1 through 8; otherwise, the SU proceeds to step 9.

1. First, all terrain range points are checked in array *terx* to ensure they are steadily increasing. If they are not, the error flag i_{error} is set equal to -17 and the SU is exited. Otherwise, the SU proceeds to step 2.

2. Next, a test is made to determine whether the first range value is zero. If it is not, the error flag i_{error} is set equal to -18 and the SU is exited. Otherwise, the SU proceeds to step 3.

3. Next, a test is made to determine if the last range point within the terrain profile meets or exceeds r_{max}. If the logical flag *lerr*6 is '.true.' and if the condition $terx_{i_{tp}} < r_{max}$ is met, then i_{error} is set equal to -6 and the SU is exited; otherwise, the SU proceeds to step 4.

4. A check is now made to determine if the specified terrain range points are spaced at fixed increments. In this procedure, three variables, $rdif_1$, r_{frac}, and r_{difsum} are initialized to $terx_2$-$terx_1$, zero, and $rdif_1$, respectively. The variable $rdif_1$ is the difference between adjacent terrain point ranges. The variable r_{frac} is the ratio between adjacent terrain point differences. The variable r_{difsum} is the running sum of adjacent terrain point differences. The final value for r_{difsum} and maximum r_{frac} are determined as

$$rdif_2 = \mathrm{MAX}\left(10^{-3},\ terx_{i+1} - terx_i\right); \quad i = 2, 3, 4, ..., i_{tp} - 1$$

$$r_{frac} = \frac{rdif_2}{rdif_1}$$

$$r_{difsum} = r_{difsum} + rdif_2,$$

where $rdif_1$ is set equal to the previous value of $rdif_2$ before each subsequent calculation of a new $rdif_2$, and r_{frac} is the maximum of all ratios computed.

5. If it is determined that the terrain points are spaced at fixed range increments, then the range spacing r_{fix} is set to this increment. Assuming that the range points are not equally spaced, r_{fix} is initially set equal to zero. If the value of r_{frac} is less than 1.05, then r_{fix} is determined from

$$r_{fix} = \mathbf{NINT}\left(\frac{r_{difsum}}{i_{tp}-1}\right).$$

6. The minimum height h_{minter} of the terrain profile is now found and the entire terrain profile is adjusted by h_{minter} such that this is the new zero reference. The adjusted terrain profile is stored in arrays tx and ty (i.e., ty = $tery$ - h_{minter} for all elements in $tery$) . Next, the maximum height h_{termax} of the terrain is also obtained from $tery$. If h_{termax} exceeds h_{max}, then i_{error} is set equal to -8 and the SU is exited. Otherwise, the SU proceeds with step 7.

7. An extra point is added to the arrays tx and ty. If $tx_{i_{tp}}$ is less than r_{max}, then $tx_{i_{tpa}}$ is set equal to r_{max} times 1.1. The input index i_{tpa} is the number of terrain points used internally in arrays tx and ty. If $tx_{i_{tp}}$ is greater or equal to r_{max}, then $tx_{i_{tpa}}$ is set equal to $tx_{i_{tp}}$ times 1.1. Finally, the array element $ty_{i_{tpa}}$ is set equal to $ty_{i_{tp}}$.

8. The variable ant_{ref} is set equal to ant_{ht} plus ty_1. Next, the array of terrain slopes, slp, and the maximum tangent ray angle, α_u, from the source to the terrain peak along the profile path are found as follows. The slope, slp_i, for each i^{th} terrain segment is given by

$$slp_i = \frac{ty_{i+1} - ty_i}{\mathbf{MAX}\left(tx_{i+1} - tx_i, 10^{-5}\right)}; \quad i = 1, 2, 3, \ldots, i_{tpa} - 1.$$

If the current slope is greater than the slope tolerance of 10^{-5}, then it is assumed that the terrain profile is no longer flat at the current range and the variable r_{flat} is set equal to tx_i. Next, if the value of ty_i is greater than ant_{ref}, then the maximum tangent angle α_u from the source to each terrain point is calculated as

$$\alpha_u = \mathbf{MAX}\left[\mathbf{TAN}^{-1}\left(\frac{ty_i - ant_{ref}}{tx_i}\right)\right]; \quad i = 1, 2, 3, \ldots, i_{tpa} - 1.$$

After α_u is determined, 0.5° is added to its value.

9. Before exiting, the minimum height hm_{ref} relative to h_{minter} is found from the difference between the minimum specified output height h_{min} and h_{minter}. The maximum height limit ht_{lim} relative to h_{minter} is given by the difference between h_{max} and h_{minter}. If the antenna height ant_{ref} is greater than ht_{lim}, the error code i_{error} is set to -9.

Table 58 and Table 59 provide identification, description, units of measure, and the computational source for each TERINIT SU input and output data element.

Table 58. TERINIT SU input data element requirements.

Name	Description	Units	Source
ant_{ht}	Transmitting antenna height above local ground	meters	Calling CSCI
f_{ter}	Logical flag indicating if terrain profile has been specified: '.true.' = terrain profile specified '.false.' = terrain profile not specified	N/A	APMINIT CSC
h_{max}	Maximum output height with respect to mean sea level	meters	Calling CSCI
h_{min}	Minimum output height with respect to mean sea level	meters	Calling CSCI
i_{tp}	Number of height/range points in profile	N/A	Calling CSCI
i_{tpa}	Number of height/range points pairs in profile *tx*, *ty*	N/A	APMINIT CSC
lerr6	User-provided error flag that will trap on certain errors if set to '.true.'	N/A	Calling CSCI
r_{max}	Maximum output range	meters	Calling CSCI
terx	Range points of terrain profile	meters	Calling CSCI
tery	Height points of terrain profile	meters	Calling CSCI

Table 59. TERINIT SU output data element requirements.

Name	Description	Units
α_u	Maximum tangent ray angle from the source to the terrain peak along profile height	radians
ant_{ref}	Transmitting antenna height relative to the reference height h_{minter}	meters
h_{minter}	Minimum height of terrain profile	meters
hm_{ref}	Height relative to h_{minter}	meters
ht_{lim}	User-supplied maximum height relative to h_{minter}, i.e., $ht_{lim}=h_{max}-h_{minter}$	meters
htermax	Maximum terrain height along profile path	meters
ierror	Integer value that is returned if errors exist in input data	N/A
rfix	Fixed range increment of terrain profile	meters
rflat	Maximum range at which the terrain profile remains flat from the source	meters
slp	Slope of each segment of terrain	N/A
tx	Range points of terrain profile	meters
ty	Adjusted height points of terrain profile	meters

Table 59. TERINIT SU output data element requirements. (continued)

Name	Description	Units
h_{termax}	Maximum terrain height along profile path	meters
i_{error}	Integer value that is returned if errors exist in input data	N/A
r_{fix}	Fixed range increment of terrain profile	meters
r_{flat}	Maximum range at which the terrain profile remains flat from the source	meters
slp	Slope of each segment of terrain	N/A
tx	Range points of terrain profile	meters
ty	Adjusted height points of terrain profile	meters

5.1.27 Trace to Output Range (TRACE_ROUT) SU

The TRACE_ROUT SU traces a single ray whose launch angle is specified by the calling routine to each output range. The height of this ray is stored at each output range for subsequent proper indexing and accessing of the appropriate sub-models.

Upon entering the SU, four in-line ray trace functions are defined for general parameters *a*, *b*, *c*, and g_{rd}: RADA1, AP, RP, and HP. These function definitions are identical to those given in Section 5.1.15.

Next, the propagation angle, range, and height at the beginning of the range step, a_0, r_0, h_0, respectively, are initialized to a_s, r_s, and h_s—the angle, range and height specified by the calling SU. The profile index *j* is also initialized to j_s from the calling SU. The index j_r is determined such that $rngout_{j_r}$ is the first range point greater than r_0. The array *harray*, containing the heights of the traced ray at each output range, is then set equal to 0 for elements 1 through j_r. Perform steps 1 through 2 for each output range step *i* from j_r to n_{rout}.

1. First, $harray_{j_r}$ is set equal to zero and the variable *ro* is set equal to $rngout_{j_r}$. Next, perform steps 1.a through 1.d until r_0 has reached *ro* or h_0 has reached ht_{lim}.

    a. First, the range, r_1, at the end of the ray trace segment is set equal to *ro*. Then the current gradient g_{rd} is set equal to $grdum_j$. The angle, a_1, at the end of the ray trace segment is found from AP(a_0, r_1-r_0).

    b. If a_1 is of the opposite sign as a_0, then a_1 is set equal to zero and r_1 is given by RP(r_0, a_1-a_0). h_1 is then given by HP(h_0, a_1, a_0).

c. Now the value of h_1 is tested. If the value of h_1 is greater than or equal to $htdum_{j+1}$, then h_1 is set equal to the minimum of ht_{lim} or $htdum_{j+1}$, and a_1, r_1 and the index j are re-computed as

$$a_1 = \sqrt{\mathbf{RADA1}(a_0, h_1 - h_0)}$$
$$r_1 = \mathbf{RP}(r_0, a_1 - a_0)$$
$$j = \mathbf{MIN}(lvlep, j+1).$$

d. If h_1 is less than $htdum_{j+1}$ but greater than ht_{lim}, then h_1 is set equal to ht_{lim} and a_1 and r_1 are re-computed as in step 1.c above. The angle, range and height variables a_0, r_0, and h_0 are now set equal to a_1, r_1, and h_1 in preparation for the next step. Steps 1.a through 1.d are repeated until $r_0 \geq ro$.

2. Once r_0 has reached ro, $harray_{j_r}$ is then set equal to h_0. The index j_r is then incremented by 1 and steps 1 through 2 are repeated for all output range steps or until h_0 has reached ht_{lim}.

Finally, if the traced ray has reached ht_{lim} at a range before r_{max}, then *harray* is set equal to ht_{lim} for elements from j_r to n_{rout}, with the index i_{hmx}, indicating the element in *harray* where this occurs, set equal to j_r.

Table 60 and Table 61 provide identification, description, units of measure, and the computational source for each TRACE_ROUT SU input and output data element.

Table 60. TRACE_ROUT SU input data element requirements.

Name	Description	Units	Source
a_s	Propagation angle for start of ray trace	radians	Calling SU
grdum	Array of refractivity gradients defined by profile *htdum* and *refdum*	M-units/ meter	REFINTER SU REFINIT SU
h_s	Height for start of ray trace	meters	Calling SU
htdum	Height array for current interpolated profile	meters	REFINTER SU REFINIT SU
ht_{lim}	User-supplied maximum height relative to h_{minter}, i.e., $ht_{lim} = h_{max} - h_{minter}$	meters	TERINIT SU
j_s	Refractive profile index for start of ray trace	N/A	Calling SU
lvlep	Number of height/refractivity levels in profile *htdum*, *refdum*	N/A	REFINIT SU
n_{rout}	Number of output height points desired	N/A	Calling CSCI
rngout	Array containing all desired output ranges	meters	APMINIT CSC
r_s	Range for start of ray trace	meters	Calling SU

Table 61. TRACE_ROUT SU output data element requirements.

Name	Description	Units
harray	Array containing heights of traced ray at every output range	meters
i_{hmx}	Index in *harray* where traced height has reached ht_{lim}	N/A

5.1.28 Trace to next Step (TRACE_STEP) SU

This SU performs one ray trace step, that, given a starting angle (a_0), range (r_0), and height (h_0), will trace to the first boundary that occurs (refractivity level or surface). It then passes back the ending angle, range, and height for this step and a flag indicating if the ray has hit the surface.

Upon entering the SU, two in-line ray trace functions are defined for general parameters *a, b, c,* and g_{rd}: RADA1, AP, HP, and RP. These function definitions are identical to those in Section 5.1.15.

From the RGTRACE SU, the range r_1 has already been incremented and is passed as part of the argument list to this SU. If the r_1 is greater than the next range point in the terrain profile, then r_1 is set equal to the range value of the next terrain point.

The refractive gradient g_{rd} within the current range step is initialized to $grdum_j$. If the gradient is less than 10^{-6}, then the new angle a_1 is set equal to the starting angle a_0 and the new height is computed as

$$h_1 = h_0 + (r_1 - r_0)\mathbf{TAN}(a_0).$$

If the new height h_1 is greater than the next level in the refractivity profile, then h_1 is set equal to the next height in the profile and r_1 is re-computed as

$$r_1 = r_0 + \frac{(h_1 - h_0)}{\mathbf{TAN}(a_0)}.$$

If the gradient is greater than 10^{-6}, then the propagation angle a_1 at the end of the range step is computed by $\mathbf{AP}(a_0, r_1 - r_0)$. Next, if $|a_0|$ is less than 10°, then if a_0 and a_1 differ in sign, a_1 is set equal to 0 and r_1 is computed from **RP**(r_0, a_1-a_0). The height of the ray at the end of the range step is next computed by **HP**(h_0, a_1, a_0). If $|a_0|$ is greater than 10°, then a_1 is set equal to a_0 and h_1 is computed as

$$h_1 = h_0 + (r_1 - r_0)\mathbf{TAN}(a_1) - \frac{(r_1 - r_0)^2}{twoka},$$

where *twoka* is determined in the GET_K SU.

Next, the HTCHECK SU is referenced to determine if the height of the ray has fallen below the elevation height of the terrain at the current range step, and if so, a new a_1, r_1, and h_1 are returned.

Next, it must be determined if the ray has passed through a refractive layer, in which case the index must be adjusted and the range, height, and angle must be computed at the refractive layer transition. For an upward ray, if a_1 is positive and h_1 has reached or surpassed the next height level, then a_1, r_1, j, and h_1, are found as follows. First, h_1 is set equal to $htdum_{j+1}$, j is increment by 1, and a_1 and r_1 are given by

$$a_1 = \sqrt{\mathrm{RADA1}(a_0, h_1 - h_0)}$$
$$r_1 = \mathrm{RP}(r_0, a_1 - a_0).$$

For a downgoing ray, if a_1 is less than or equal to 0, and h_1 is less than $htdum_j$, then h_1 is set equal to $htdum_j$, and j is set equal to the maximum of 0 or j-1. The variables a_1 and r_1 are then determined from

$$a_1 = -\sqrt{\mathrm{RADA1}(a_0, h_1 - h_0)}$$
$$r_1 = \mathrm{RP}(r_0, a_1 - a_0).$$

Finally, the HTCHECK SU is referenced once again before exiting to determine if this new value of h_1 has fallen below the height of the current terrain elevation.

Table 62 and Table 63 provide identification, description, units of measure, and the computational source for each TRACE_STEP SU input and output data element.

Table 62. TRACE_STEP SU input data element requirements.

Name	Description	Units	Source
a_0	Propagation angle at the start of the ray trace step	radians	Calling SU
f_{ter}	Logical flag indicating if terrain profile has been specified: '.true.' = terrain profile specified '.false.' = terrain profile not specified	N/A	APMINIT CSC
grdum	Array of refractivity gradients defined by profile *htdum* and *refdum*	M-units/ meter	REFINTER SU REFINIT SU
h_0	Height at the start of the ray trace step	meters	Calling SU
htdum	Height array for current interpolated profile	meters	REFINTER SU REFINIT SU
it	Index of the current terrain segment in arrays *tx* and *ty*	N/A	Calling SU

Table 62. TRACE_STEP SU input data element requirements. (continued)

Name	Description	Units	Source
j_l	Refractive profile index at the start of the ray trace step	N/A	Calling SU
r_0	Range at the start of the ray trace step	meters	Calling SU
twoka	Twice the effective earth radius	meters	GET_K SU
tx	Range points of terrain profile	meters	TERINIT SU
ty	Height points of terrain profile	meters	TERINIT SU

Table 63. TRACE_STEP SU output data element requirements.

Name	Description	Units
a_1	Propagation angle at the end of the ray trace step	radians
g_{rd}	Gradient of the ray trace step	M-units/meter
h_1	Height at the end of the ray trace step	meters
i_{error}	Integer value that is returned if any errors exist in the computation	N/A
ihit	Integer flag indicating if ray has hit surface: *ihit* = 0; ray has not hit the surface *ihit* =1; ray has hit the surface	N/A
r_1	Range at the end of the ray trace step	meters

5.1.29 Troposcatter Initialization (TROPOINIT) SU

The TROPOINIT SU initializes all variables and arrays needed for subsequent troposcatter calculations. The tangent range and tangent angle are determined from the source and the tangent range and tangent angles are determined for all receiver heights and stored in arrays.

Upon entering the SU, the array $\vartheta 1t$ is allocated for size i_{PE} and initialized to 0. Next, the GET_K SU is referenced to determine the effective earth radius factor a_{ek} based on a ray launched at the critical angle traced to ht_{lim}. The array $\vartheta 0$, containing angles used in determining the common volume scattering angle is then determined from

$$\vartheta 0_i = \frac{rngout_i}{a_{ek}}; \quad \text{for } i = 1,2,3,\ldots, n_{rout} .$$

A constant needed in the troposcatter calculation, r_f, is determined from 0.0419 times the frequency f_{MHz}. A second constant needed in the troposcatter calculation, rt_1, is found from r_f times the adjusted transmitting antenna height ant_{ref}.

Next, the tangent angle from the source, $\vartheta 1_s$, for smooth surface is computed from

$$\vartheta 1_s = \frac{\sqrt{twoka * ant_{ref}}}{a_{ek}} .$$

The variable α_{ld} is determined from

$$\alpha_{ld} = 20\,\mathrm{LOG}_{10}\left(f\left(\alpha_d\right)\right)$$
$$\alpha_d = \vartheta 1_s + 10^{-6} ,$$

where α_d represents the lowest direct ray angle in the RO region, and $f(\alpha_d)$ is the antenna pattern factor, obtained from referencing the ANTPAT SU, for the direct angle.

The minimum range, r_{hor1}, at which the diffraction field solutions are applicable and the intermediate region ends, is determined for smooth surface and zero receiver height. The variable r_{hor1} is given by

$$r_{hor1} = \sqrt{twoka * ant_{ref}} .$$

Next, the tangent ranges and angles for all output receiver heights are computed and stored in arrays $d2s$ and $\vartheta 2s$, respectively. The minimum ranges at which diffraction field solutions are applicable (for smooth surface) for all output receiver heights are determined and stored in array rdt. Height differences between ant_{ref} and each output receiver height are also computed and stored in $adif$. These arrays are given by

$$\begin{aligned} d2s_i &= \sqrt{2a_{ek}\, zout_i}, \\ \vartheta 2s_i &= -\frac{d2s_i}{a_{ek}}, \\ rdt_i &= r_{hor1} + d2s_i \\ adif_i &= ant_{ref} - zout_i, \end{aligned} \qquad i = 0, 1, 2, \ldots, n_{zout}$$

where the computation is performed for each i^{th} output receiver height $zout_i$, provided $zout_i$ is greater than or equal to 0, and i ranges from 1 to n_{zout}.

If f_{ter} is '.true.', then the tangent angles $\vartheta 1t$ from the source at every PE range is determined as

$$\vartheta 1t = \frac{ant_{ref} - tyh_j}{j\Delta r_{PE}} + \frac{j\Delta r_{PE}}{twoka}, \quad j = 1, 2, 3, \ldots, i_{PE} .$$

The index counter j_{t2} (used in the TROPOSCAT SU) is initialized to 1. Finally, the troposcatter loss term $tlst_{wr}$, used in the TROPOSCAT SU is given by

$$tlst_{wr} = 54.9 + 30\,\mathbf{LOG}_{10}\left(f_{MHz}\right) - \alpha_{ld} \ .$$

Table 64 and Table 65 provide identification, description, units of measure, and the computational source for each TROPOINIT SU input and output data element.

Table 64. TROPOINIT SU input data element requirements

Name	Description	Units	Source
ant_{ref}	Transmitting antenna height relative to h_{minter}	meters	TERINIT SU
f_{MHz}	Frequency	MHz	Calling CSCI
f_{ter}	Logical flag indicating if terrain profile has been specified: '.true.' = terrain profile specified '.false.' = terrain profile not specified	N/A	APMINIT CSC
i_{PE}	Number of PE range steps	N/A	PEINIT SU
n_{rout}	Integer number of output range points desired	N/A	Calling CSCI
n_{zout}	Integer number of output height points desired	N/A	Calling CSCI
$rngout$	Array containing all desired output ranges	meters	APMINIT CSC
tyh	Adjusted height points of terrain profile at every PE range step	meters	PEINIT SU
$zout$	Array containing all desired output heights referenced to h_{minter}	meters	APMINIT CSC

Table 65. TROPOINIT SU output data element requirements.

Name	Description	Units
a_{ek}	Effective earth radius	meters
$adif$	Height differences between ant_{ref} and all output receiver heights	meters
$d2s$	Array of tangent ranges for all output receiver heights over smooth surface	meters
e_k	Effective earth radius factor	N/A
i_{error}	Integer value that is returned if any errors exist in the computation	N/A
$jt2$	Index counter for tx and ty arrays indicating location of receiver range	N/A
r_{hor1}	Minimum range at which diffraction field solutions are applicable and the intermediate region ends, for smooth surface and 0 receiver height.	meters
rdt	Array of minimum ranges at which diffraction field solutions are applicable (for smooth surface) for all output receiver heights.	meters
rf	Constant used for troposcatter calculations	meters^{-1}
rt_1	rf multiplied by ant_{ref}	N/A

Table 65. TROPOINIT SU output data element requirements. (continued)

Name	Description	Units
$\vartheta 0$	Array of angles used to determine common volume scattering angle	radians
$\vartheta 1_s$	Tangent angle from source (for smooth surface)	radians
$\vartheta 1t$	Array of tangent angles from source height – used with terrain profile	radians
$\vartheta 2s$	Array of tangent angles from all output receiver heights – used with smooth surface	radians
$tlst_{wr}$	Troposcatter loss term used in the TROPOSCAT SU	dB
twoka	Twice the effective earth radius	meters

5.1.30 Starter Field Initialization (XYINIT) SU

The XYINIT SU calculates the complex PE solution at range zero.

Upon entering this SU, several constant terms that will be employed over the entire PE mesh are calculated. The PE mesh is defined by the number of points in the mesh, n_{fft}, and by the mesh size, Δp. The constant terms include (1) the angle difference between mesh points in p-space $\Delta\theta$; (2) a height-gain value at the source (transmitter) $antk_o$; and (3) the normalization factor s_{gain} used in the determination of the complex array containing the field U. The normalization factor s_{gain} is given by

$$s_{gain} = \frac{\sqrt{\lambda}}{z_{max}} .$$

The height-gain value $antk_o$ at the source (transmitter) is given by

$$antk_o = k_o\, ant_{ht} ,$$

where ant_{ht} is the transmitting antenna height above the local ground in meters.

The complex PE solution U is determined from the antenna pattern factors, elevation angle, and normalization factor according to

$$\begin{aligned}
U_j &= c_a s_{gain}\left[f(\alpha_d)e^{-ip_j antk_o} - f(-\alpha_d)e^{ip_j antk_o}\right]; \quad \text{H pol}\\
U_j &= c_a s_{gain}\left[f(\alpha_d)e^{-ip_j antk_o} + f(-\alpha_d)e^{ip_j antk_o}\right]; \quad \text{V pol}\\
\alpha_d &= \mathrm{SIN}^{-1}(p_j),\\
c_a &= \left(1 - p_j^2\right)^{-3/4},
\end{aligned}$$

where $p_j = j\Delta\theta$ and the antenna pattern factors $f(\alpha_d)$ for the direct path and $f(-\alpha_d)$ for the reflected path are determined by referencing the ANTPAT SU. The index j varies from 0 to n_{fft}.

Next, the upper ¼ of the field is filtered. A cosine-tapered (Tukey) filter array *filt* is used for this purpose. The filtered PE field U is given by

$$U_j = filt_{j-n34} U_j ; \qquad j = n_{34}, n_{34}+1, n_{34}+2, ..., n_{fft} .$$

Finally, the DRST SU is referenced for both the real and imaginary components to transform the complex PE field to z-space before exiting the SU.

Table 66 and Table 67 provide identification, description, units of measure, and the computational source for each XYINIT SU input and output data element.

Table 66. XYINIT SU input data element requirements.

Name	Description	Units	Source
ant_{ht}	Transmitting antenna height above local ground	meters	Calling CSCI
$\Delta\theta$	Angle bin width (i.e., incremental sine(theta))	radians	PEINIT SU
filt	Cosine-tapered (Tukey) filter array	N/A	PEINIT SU
i_{pol}	Polarization flag: 0 = horizontal polarization 1 = vertical polarization	N/A	Calling SU
k_o	Free-space wave number	meters^{-1}	APMINIT CSC
λ	Wavelength	meters	APMINIT CSC
ln_{fft}	Power of 2 transform size, i.e. $n_{fft}=2^{ln_{fft}}$	N/A	FFTPAR SU
n_{fft}	Transform size	N/A	FFTPAR SU
n_{34}	¾ n_{fft}	N/A	APMINIT CSC
z_{max}	Total height of the FFT/PE calculation domain	meters	FFTPAR SU

Table 67. XYINIT SU Output Data Element Requirements

Name	Description	Units
U	Transform of complex field	μV/m

5.2 ADVANCED PROPAGATION MODEL STEP (APMSTEP) CSC

The APMSTEP SU advances the entire APM CSCI algorithm one output range step, referencing various SUs to calculate the propagation loss at the current output range.

Upon entering the APMSTEP SU, the current output range r_{out} is updated, the gaseous absorption loss, gas_{loss} (in dB), and all *mpfl* array integer indices for the various calculation regions are initialized. The *propaf* array is also initialized to a value of -999. The PESTEP SU is then referenced to determine all propagation loss values within the PE calculation region. If the PE-only option is specified (PE_{flag} = '.true.'), then *mpfl* is returned with integer indices j_{ps} and j_{pe}, corresponding to the start and end, respectively, of propagation factor and loss values within *mpfl*. Otherwise, the SU proceeds with steps 1 through 3.

1. If APM is executing under the airborne mode ($i_{hybrid} = 0$), then the starting index j_{as} for the lower angular region is initialized to the maximum of 0 and i_{zg} plus i_o. The ending index within this region j_{ae} is determined by performing an iterative search to find the index at which the first occurance of $zout_j$ is greater than $htfe_{i_{stp}}$. j_{ae} is then set equal to the index j. The FEDR SU is then referenced to compute the loss for the lower FE region for the direct ray only, provided j_{as} is less than j_{ae}. Upon returning, j_{start} is then set equal to j_{as}, j_{as} is set equal to $j_{pe}+1$, j_{ae} is set equal to n_{zout}, and the FEDR SU is again referenced to compute the loss for the upper FE region. The SU then proceeds with step 3.

2. If APM is executing under the full hybrid mode ($i_{hybrid} = 1$) and the current output range is less than the range at which the XO region begins ($r_{out} < r_{tst}$), the steps 2.a and 2.b are performed.

   a. The starting and ending *mpfl* array indices for FE calculations, j_{fs} and j_{fe}, respectively, are determined. For ranges less than 2.5 km, j_{fs} is set equal to the maximum of 0 and i_{zg} plus i_o, and j_{fe} is set equal to n_{zout}. For ranges greater than 2.5 km, j_{fs} is set equal to the maximum of $j_{pe}+1$, or $j+1$, where j is the first occurance of $zout_j$ that is greater than $htfe_{i_{stp}}$ (the output height index that corresponds to the height just above the FE 5° angle limit). The ending index j_{fe} is set equal to n_{zout}. The FEM SU is then referenced and propagation factor and loss values within the FE region are computed and returned in *mpfl*.

   b. If the current output range is greater than 2.5 km, then the starting and ending *mpfl* array indices for RO calculations, j_{rs} and j_{re}, respectively, are determined. These indices are based on the values of j_{ps}, j_{pe}, j_{fs}, and j_{fe} such that at every range step, j_{rs} will always be greater than the ending index of the PE region (j_{pe}) and j_{re} will be less than the starting index of the FE region (j_{fs}). The ROLOSS SU is then referenced and propagation factor and loss values within the RO region are computed and returned in *mpfl*.

3. Once the various propagation factor and loss within the various regions have been calculated, the ending index j_{end} of valid values within *mpfl* is given by the maximum of j_{pe}, j_{fe}, j_{re}, and j_{ae}.

Upon exiting, if the final output range step has been reached, the integer counter j_{t2}, associated with troposcatter calculations, is initialized to 1.

Table 68 and Table 69 provide identification, description, units of measure, and the computational source for each APMSTEP SU input and output data element.

Table 68. APMSTEP CSC input data element requirements.

Name	Description	Units	Source
gas_{att}	Gaseous absorption attenuation rate	dB/km	GASABS SU
htfe	Array containing the height at each output range separating the FE region from the RO region (full hybrid mode), or the FE region from the PE region (partial hybrid mode)	meters	FILLHT SU
ht_{lim}	Maximum height relative to h_{minter}	meters	TERINIT SU
i_{hybrid}	Integer indicating which sub-models will be used: 0 = FEDR + PE model 1 = full hybrid model (PE + FE + RO + XO) 2 = partial hybrid model (PE + XO)	N/A	APMINIT CSC
i_o	Starting index for *mpfl* array: 0 = 1st calculated output point is at surface 1 = 1st calculated output point is at height Δz_{out}	N/A	APMINIT CSC
i_{stp}	Current output range step index	N/A	Calling CSCI
i_{zg}	Number of output height points corresponding to local ground height at current output range r_{out}	N/A	CALCLOS SU
no_{PE}	Integer flag indicating if PE calculations are needed: 0 = PE calculations needed 1 = no PE calculations needed	N/A	GETTHMAX SU
nrout	Integer number of output range points desired	N/A	Calling CSCI
nzout	Integer number of output height points desired	N/A	Calling CSCI
PE_{flag}	Flag to indicate use of PE algorithm only: '.true.' = only use PE sub-model '.false.' = use automatic hybrid model	N/A	Calling CSCI
r_{atz}	Range at which z_{lim} is reached (used for hybrid model)	meters	APMINIT CSC
rngout	Array containing all desired output ranges	meters	APMINIT CSC
r_{pest}	Range at which loss values from the PE model will start being calculated	meters	GETTHMAX SU
r_{tst}	Range at which to begin RO calculations (equal to 2.5 km)	meters	APM_MOD
zout	Array containing all desired output heights referenced to hminter	meters	APMINIT CSC

Table 69. APMSTEP CSC output data element requirements.

Name	Description	Units
j_{end}	Index at which valid loss values in *mpfl* end	N/A
j_{start}	Index at which valid loss values in *mpfl* start	N/A
gas_{loss}	Gaseous absorption loss at range r_{out}	dB
jt2	Index counter for *tx* and *ty* arrays indicating location of receiver range	N/A
mpfl	Propagation factor and loss array	cB
mpfl_rtg	Propagation loss and factor at receiver heights specified in the *zout_rtg* array	cB
r_{out}	Current desired output range	meters
propaf	Two-dimensional array, containing the propagation angles and factors for the direct and reflected rays (where applicable) for all output height/range points	radians, dB

5.2.1 Calculate Propagation Loss (CALCLOS SU)

The CALCLOS SU determines the propagation factor and loss from the PE region at each output height point at the current output range.

Upon entering the SU, several variables are initialized. The output range, r_{out}, is updated based on the current range step i_{stp}. The height of the terrain at the current and last ranges, y_{ch} and y_{lh}, respectively, are determined relative to the reference height, hm_{ref}.

Next, the interpolated ground height, z_{int}, at the current output range and the number of vertical output points, i_{zg}, that correspond to this ground height are determined. First, the interpolated ground height is given by

$$z_{int} = y_{last} + \left(y_{cur} - y_{last}\right)xx \ ,$$

where the parameter xx is given in terms of the PE range step Δr_{PE} by

$$xx = \frac{r_{out} - r_{last}}{\Delta r_{PE}} \ .$$

Having determined z_{int}, i_{zg} is then computed from

$$i_{zg} = \mathbf{INT}\left(\frac{z_{int} - hm_{ref}}{\Delta z_{out}}\right),$$

where Δz_{out} is the output height increment. Next, all elements in array *mpfl* from 1 to i_{zg} are set to zero, and the index j_{start}, representing beginning valid loss values in the *mpfl* array, is set to the maximum of 0 or i_{zg}, plus i_o.

If i_{hybrid} = 0, then the maximum tangent angle α_{ter} from the antenna height to the terrain height at the current range is determined from

$$\alpha_{ter} = \mathbf{MAX}\left[\mathbf{TAN}^{-1}\left(\frac{z_{int} - ant_{ref} - \dfrac{r_{out}^2}{twoka_{down}}}{r_{out}}\right), \alpha_{ter}\right],$$

where α_{ter} in the argument above is the maximum angle computed from previous references to the CALCLOS SU.

If the current output range is greater than the range r_{pest} at which PE solutions are valid, then the calculation of loss values is begun. If this condition is not satisfied, then the *mpfl* array is set to -32767 for values of the array index from j_{start} up to and including the number of output height points desired (n_{zout}), j_{end} is set equal to j_{start} and the SU is exited.

Once it is determined that loss calculations will be performed, several parameters are computed. Both parameters i_{p1} and i_{p2} are first set to 0. If the logical variable f_{ter} is '.true.', then a terrain case is being performed. The two indices i_{p1} and i_{p2} are given by

$$i_{p1} = \mathbf{MAX}\left(0, \mathbf{INT}\left\{\frac{y_{lh}}{\Delta z_{out}}\right\}\right)$$

$$i_{p2} = \mathbf{MAX}\left(0, \mathbf{INT}\left\{\frac{y_{ch}}{\Delta z_{out}}\right\}\right).$$

These indices indicate the first output height point in array *zout*, where propagation loss will be computed at the last and current PE ranges. Next, the output heights $zout_{i_{p1}}$ and $zout_{i_{p2}}$, relative to y_{last} and y_{cur}, respectively, are checked to make sure they are positive. If not, the two indices i_{p1} and i_{p2} are incremented by a value of 1. For values of the array index from 0 up to i_{p1}, the array of propagation factors *rfac*1 at valid height points for range r_{last} are set to 0. For values of the array index from 0 up to i_{p2}, the array of propagation factors *rfac*2 at valid height points for range r_{out} are also set 0.

If j_{start} is less than i_{p1} and i_{p2}, then the variable i_{zg} is recomputed as

$$i_{zg} = \mathbf{MAX}\left(i_{zg}\mathbf{,}\ \mathbf{MIN}\left(i_{p1}\mathbf{,}\ i_{p2}\right)\right)$$

and the *mpfl* array at index i_{zg} is set equal to -32766. j_{start} is then recomputed as the maximum of 0 and i_{zg}, and the value of i_o is then added to j_{start}.

Next, the height/integer value, j_{end}, indicating the end of valid loss values, is determined as

$$j_{end} = \mathbf{MAX}\left[0\mathbf{,}\ \mathbf{INT}\left(\frac{z_{lim} - hm_{ref}}{\Delta z_{out}}\right)\right] \quad if\ PE_{flag}\ is\ '.true.'\mathbf{,}\ otherwise$$

$$j_{end} = \mathbf{MAX}\left(0\mathbf{,}\mathbf{INT}\left\{\frac{\mathbf{MIN}\left[z_{lim}\mathbf{,}\mathbf{MAX}\left(z_{int}\mathbf{,}hlim_{i_{stp}}\right)\right] - hm_{ref}}{\Delta z_{out}}\right\}\right)\mathbf{.}$$

where i_{stp} is the current output range step, and $hlim_{i_{stp}}$ is the height at the current output range step separating the PE region from the FE, RO, or XO regions. Finally, j_{end} is given by the minimum of j_{end} (as computed above) and n_{zout}.

If clutter calculations are to be performed (C_{lut} = ‘.true.), the propagation factor at 1 m above the surface is computed by referencing the FN_GETPFAC function. The propagation factor at 1-m height is computed from the complex PE field at the range step immediately before and after the current output range step by

$$rf1 = \mathbf{FN\_GETPFAC}\left(Ulast\mathbf{,}\ r_{loglst}\mathbf{,}\ \Delta z_{PE}\mathbf{,}1\mathbf{.}0\right),$$
$$rf2 = \mathbf{FN\_GETPFAC}\left(U\mathbf{,}\ r_{log}\mathbf{,}\ \Delta z_{PE}\mathbf{,}1\mathbf{.}0\right).$$

The propagation factor is then interpolated in range to the current output range step by referencing the FN_PLINT function:

$$Fat1m_{i_{stp}} = \mathbf{FN\_PLINT}\left(rf1\mathbf{,}\ rf2\mathbf{,}\ xx\right).$$

Next, if the value of j_{end} is less than j_{start} the *mpfl* array for indices from j_{end}+1 to n_{zout} are set equal to -32767 and the SU is exited. Otherwise, the propagation loss values are determined from the propagation factors $rfac1_i$ and $rfac2_i$ and from the parameter *xx* defined earlier in this section.

If r_{loglst} ($10\,\mathrm{LOG}(r_{last})$) is greater than zero (it is initialized to 0 for i_{stp}=1), then the FN_GETPFAC function is referenced to determine the propagation factor $rfac1_i$, which is given by

$$rfac1_i = \mathbf{FN\_GETPFAC}\left(Ulast, r_{loglst}, \Delta z_{PE}, zout_i - y_{last}\right), \quad i = i_{p1}, i_{p1}+1, ..., j_{end} ,$$

where *Ulast* is the complex field array at the previous PE range. Next, the propagation factor $rfac2_i$ is given by

$$rfac2_i = \mathbf{FN\_GETPFAC}\left(U, r_{log}, \Delta z_{PE}, zout_i - y_{cur}\right), \quad i = i_{p2}, i_{p2}+1, ..., j_{end} ,$$

where *U* is the complex field array at the current PE range, and r_{log} is $10\,\mathrm{LOG}(r)$.

Next, if a frequency is specified greater than 50 MHz (HF_{flag} = '.false.') and if using the partial hybrid mode (PE & XO models), heights corresponding to areas outside the valid PE calculation region are determined and propagation loss is set equal to -32767 within *mpfl* for those heights. If using the full or partial hybrid modes, the propagation factor at the last PE height point is determined at the previous and current PE ranges. Linear interpolation is then performed to compute the propagation loss at range r_{out} and height z_{lim}. The loss and height are then stored in array *ffrout* for subsequent interpolation in the EXTO SU.

Next, the propagation factor and loss at range r_{out} is found by interpolating between the current and previous PE ranges. The propagation factor in dB, and the propagation loss at range r_{out} is given by

$$\left.\begin{aligned} F_{dB} &= \mathbf{FN\_PLINT}\left(rfac1_i, rfac2_i, xx\right) \\ rloss_i &= fsl_{i_{stp}} - F_{dB} \end{aligned}\right\} ; \quad i = j_{start}, j_{start}+1, \ldots, j_{end}$$

where $fsl_{i_{stp}}$ is the free-space loss in dB at range r_{out}.

Next, if the propagation factor <u>and</u> propagation angle and are to be computed (*lang* = '.true.'), the angle information is stored in array *propaf* by interpolating in height using the values stored in *ptr* at the current range step. The propagation angle at the current range step is determined by

$$zf = \frac{zout_k - z_{int}}{\Delta z_{spec}},$$
$$izsp = \mathbf{INT}(zf),$$
$$fr = zf - izsp,$$
$$propaf_{1,k} = \mathbf{FN\_PLINT}\left(ptr_{izsp, i_{stp}}, ptr_{izsp+1, i_{stp}}, fr\right); \quad k = j_{start}, j_{start}+1, ..., j_{end},$$

where Δz_{spec} is the height increment at which the propagation angles were spectral estimated.

If the loss at a receiver height relative to the local ground height is to be computed (*lrtg* = '.true.'), then the propagation loss at each height specified in array *zout_rtg* is computed by subsequent references to the FN_GETPFAC function using the field strength arrays at the previous and next PE range steps. The final propagation loss is then interpolated by referencing the FN_PLINT function and stored in array *rloss_rtg*.

If the troposcatter calculation flag T_{ropo} is '.true.' and the transmitter height is less than 100 m, then the TROPOSCAT SU is referenced to compute troposcatter loss from height $zout_{j_{start}}$ to $zout_{j_{end}}$, and this is added, if necessary, to *rloss*.

The gaseous absorption loss gas_{loss} is next added to *rloss* and the loss and propagation factor in centibels is given by

$$\begin{aligned} mpfl_{1,i} &= \mathbf{NINT}(10 * rloss_i) \\ mpfl_{2,i} &= \mathbf{NINT}\left(10 * \left(fsl_{i_{stp}} - rloss_i\right)\right); \quad i = j_{start}, j_{start}+1, \ldots, j_{end} \end{aligned}$$

with the remaining elements in *mpfl* set equal to -32767 (i.e., $mpfl_k$=-32767 for $k = j_{end}+1$ to n_{zout}).

Finally, if *lang* and *lrtg* are '.true.', then the complete propagation factor is computed from *mpfl* and *rloss_rtg* and stored in arrays *propaf* and *mpfl_rtg*, respectively, before exiting.

Table 70 and Table 71 provide identification, description, units of measure, and the computational source for each CALCLOS SU input and output data element.

Table 70. CALCLOS SU input data element requirements.

Name	Description	Units	Source
ant_{ref}	Transmitting antenna height relative to the reference height h_{minter}	meters	TERINIT SU
C_{lut}	Logical flag used to indicate if surface clutter calculations are desired.	logical	Calling CSCI
Δr_{PE}	PE range step	meters	PEINIT SU
Δz_{out}	Output height increment	meters	APMINIT CSC
Δz_{PE}	PE mesh height increment (bin width in z-space)	meters	FFTPAR SU
Δz_{spec}	Height increment at which the propagation angles are computed from spectral estimation	meters	GETANGLES SU
fsl	Free space loss array for output ranges	dB	APMINIT CSC

Table 70. CALCLOS SU input data element requirements. (continued)

Name	Description	Units	Source
f_{ter}	Logical flag indicating if terrain profile has been specified: .true. = terrain profile specified .false. = terrain profile not specified	N/A	APMINIT CSC
gas_{loss}	Gaseous absorption loss at range r_{out}	dB	APMSTEP CSC
HF_{flag}	HF computation flag indicating the frequency specified is less than 50 MHz	N/A	APMINIT CSC
$hlim$	Array containing height at each output range separating the RO region from the PE (at close ranges) and XO (at far ranges) regions	meters	GETTHMAX SU
h_{minter}	Minimum height of terrain profile	meters	TERINIT SU
hm_{ref}	Height relative to h_{minter}	meters	TERINIT SU
$htfe$	Array containing the height at each output range separating the FE region from the RO region (full hybrid mode), or the FE region from the PE region (partial hybrid mode)	meters	FILLHT SU
i_{hmx}	Index in $harray$ where traced height has reached ht_{lim}	N/A	TRACE_ROUT SU
i_{hybrid}	Integer indicating which sub-models will be used: 0 = pure PE model 1 = full hybrid model (PE + FE + RO + XO) 2 = partial hybrid model (PE + XO)	N/A	APMINIT CSC
i_o	Starting index for $mpfl$ array: 0 = 1st calculated output point is at surface 1 = 1st calculated output point is at height Δz_{out}	N/A	APMINIT CSC
i_{stp}	Current output range step index	N/A	Calling SU
i_{xo}	Number of range steps in XO calculation region	N/A	APMINIT CSC
$lang$	Logical flag indicating if propagation angle and propagation factor output is desired.	N/A	Calling CSCI
$lrtg$	Logical flag indicating if loss relative to the local ground height needs to be computed. '.true.' = Compute loss relative to ground at heights specified by array $zout\_rtg$. '.false.' = Do not compute loss.	N/A	APMINIT CSC
n_{ang}	Number of points in the vertical at which to spectrally estimate propagation angles.	N/A	GETANGLES SU
n_{zout}	Integer number of output height points desired	N/A	Calling CSCI
n_{zout_rtg}	Number of height output points for receiver heights relative to the local ground elevation.	N/A	Calling CSCI
PE_{flag}	Flag to indicate use of PE algorithm only: '.true.' = only use PE sub-model '.false.' = use automatic hybrid model	N/A	Calling CSCI
r_{atz}	Range at which z_{lim} is reached (used for hybrid model)	meters	APMINIT CSC

Table 70. CALCLOS SU input data element requirements. (continued)

Name	Description	Units	Source
r_{last}	Previous PE range	meters	Calling SU
r_{log}	10 log(PE range r)	N/A	PESTEP SU
r_{loglst}	10 log(previous PE range r_{last})	N/A	PESTEP SU
$rngout$	Array containing all desired output ranges	meters	APMINIT CSC
r_{pest}	Range at which PE loss values will start being calculated	meters	GETTHMAX SU
T_{ropo}	Troposcatter calculation flag: ‘.false.’= no troposcatter calcs ‘.true.’ = troposcatter calcs	N/A	Calling CSCI
$twoka_{down}$	Twice the effective earth radius for downward path	meters	GET_K SU
U	Complex field at current PE range r	μV/m	PESTEP SU
$Ulast$	Complex field at previous PE range r_{last}	μV/m	PESTEP SU
y_{cur}	Height of ground at current range r	meters	PESTEP SU
y_{last}	Height of ground at previous range r_{last}	meters	PESTEP SU
$zlim$	Height limit for PE calculation region	meters	GETTHMAX SU
$zout$	Array containing all desired output heights referenced to h_{minter}	meters	APMINIT CSC
$zout\_rtg$	Dynamically allocated array of receiver heights specified relative to the local ground height.	meters	Callng CSCI

Table 71. CALCLOS SU output data element requirements.

Name	Description	Units
α_{ter}	Tangent angle from antenna height to terrain height at current range	radians
$Fat1m$	Propagation factor computed at 1 m above the surface.	dB
$ffrout$	Array of propagation factors at each output range beyond r_{atz} and at height z_{lim}	dB
i_{zg}	Number of output height points corresponding to local ground height at current output range r_{out}	N/A
j_{end}	Index at which valid loss values in $mpfl$ end	N/A
j_{start}	Index at which valid loss values in $mpfl$ begin	N/A
$mpfl$	Two-dimensional propagation factor and loss array	cB
$mpfl\_rtg$	Propagation loss and factor at receiver heights specified in the $zout\_rtg$ array	cB
$propaf$	Two-dimensional array, containing the propagation angles and factors for the direct and reflected rays (where applicable) for all output height/range points	radians,dB
$rfac1$	Propagation factor at valid output height points from PE field at range r_{last}.	dB
$rfac2$	Propagation factor at valid output height points from PE field at range r	dB

Table 71. CALCLOS SU output data element requirements. (continued)

Name	Description	Units
rloss	Propagation loss	dB
rloss_rtg	Propagation loss determined at receiver heights specified in array *zout_rtg*	dB
zxo	Height of the ground at the current output range step	meters

5.2.2 Current Wind (FN_CURWIND) Function

The FN_CURWIND function performs a linear interpolation in range to get the current wind speed at the specified range.

Upon entry, the current wind speed, ω_s, is initialized to the the final wind speed specified in array *wind*. If the number of wind speeds specified is greater than 1 then the index, *k*, within the array *rngwind* is determined such that the current range, *r*, satisfies $rngwind_k < r < rngwind_{k+1}$. The wind speed at range *r* is then determined from linear interpolation:

$$\omega_s = wind_k + \left(wind_{k+1} - wind_k\right)\left(\frac{r - rngwind_k}{rngwind_{k+1} - rngwind_k}\right),$$

and returned to the calling SU.

Table 72 and Table 73 provide identification, description, units of measure, and the computational source for each FN_CURWIND function input and output data element.

Table 72. FN_CURWIND function input data element requirements.

Name	Description	Units	Source
nw	Number of wind speeds	N/A	Calling CSCI
r	Current range	meters	Calling SU
rngwind	Ranges of wind speeds entered: $rngwind_i$ = range of i^{th} wind speed	meters	Calling CSCI
wind	Dynamically allocated array of wind speeds.	meters/ second	Calling CSCI

Table 73. FN_CURWIND function output data element requirements.

Name	Description	Units
ω_s	Interpolated wind speed	meters/second

5.2.3 Dielectric Constant (FN_DIECON) Function

The FN_DIECON function extracts the complex dielectric constant at the current range.

Upon entering the function, the index, k, within the array *rgrnd* is determined such that the current range, r, satisfies $rgrnd_k < r < rgrnd_{k+1}$. The complex dielectric constant is then returned according to $diec = nc^2{}_k$, and the function is exited.

Table 74 and Table 75 provide identification, description, units of measure, and the computational source for each FN_DIECON function input and output data element.

Table 74. FN_DIECON function input data element requirements.

Name	Description	Units	Source
i_{gr}	Number of different ground types specified	N/A	Calling CSCI
nc^2	Array of complex dielectric constants	N/A	DIEINIT SU
r	Current range	meters	Calling SU
rgrnd	Array containing ranges at which varying ground types apply.	meters	Calling CSCI

Table 75. FN_DIECON function output data element requirements.

Name	Description	Units
diec	Complex dielectric constant at range r	N/A

5.2.4 DOSHIFT SU

The DOSHIFT SU shifts the field by the number of bins, or PE mesh heights corresponding to the local ground height.

Upon entry, the number of bins to be shifted is determined. First, the difference y_{diff} between the height of the ground y_{last} at the previous range and that at the current PE range y_{cur} is determined from

$$y_{diff} = y_{cur} - y_{last} .$$

The number of bins to be shifted, k_{bin}, is found from

$$k_{bin} = \mathbf{NINT}\left(\frac{|y_{diff}|}{\Delta z_{PE}} \right) .$$

The PE solution U is then shifted downward if the local ground is currently at a positive slope ($y_{diff} > 0$), upward if the local ground is at a negative slope ($y_{diff} < 0$), and otherwise not shifted. When the PE solution has been shifted down, the value of the PE solution U for the upper k_{bin} elements are set to zero. Likewise, when the PE solution has been shifted upwards, the lower k_{bin} elements are set to zero.

Table 76 and Table 77 provide identification, description, units of measure, and the computational source for each DOSHIFT SU input and output data element.

Table 76. DOSHIFT SU input data element requirements.

Name	Description	Units	Source
Δz_{PE}	PE mesh height increment (bin width in z-space)	meters	FFTPAR SU
n_{fft}	Transform size	N/A	FFTPAR SU
n_{m1}	n_{fft} -1	N/A	PEINIT SU
U	Complex field at range r	μV/m	PESTEP SU
y_{cur}	Height of ground at current range r	meters	PESTEP SU
y_{last}	Height of ground at previous range r_{last}	meters	PESTEP SU

Table 77. DOSHIFT SU output data element requirements.

Name	Description	Units
U	Complex field at range r	μV/m

5.2.5 Discrete Sine/Cosine Fast-Fourier Transform (DRST) SU

A function with a common period, such as a solution to the wave equation, may be represented by a series consisting of sines and cosines. This representation is known as a Fourier series. An analytical transformation of the function, known as a Fourier transform, may be used to obtain a solution for the function.

The solution to the PE approximation to Maxwell's wave equation is obtained by using such a Fourier transformation function. The APM CSCI uses only the real-valued sine or cosine transformation in which the real and imaginary parts of the PE equation are transformed separately. Which transform is performed is dependent on the value of an

integer flag provided by the calling SU. The Fourier transformation provided with the APM CSCI is described by Bergland (1969) and Cooley (1970).

Other sine/cosine fast Fourier transform (FFT) routines are available in the commercial market, and such a sine/cosine FFT may already be available within another calling CSCI. The selection of which FFT ultimately used by the APM CSCI is left to the application designer as every sine/cosine FFT will have hardware and/or software performance impacts. For this reason, it is beyond the scope of this document to describe the numerical implementation of the FFT algorithm.

Table 78 and Table 79 provide identification, description, units of measure, and the computational source for each DRST SU input and output data element.

Table 78. DRST input data element requirements.

Name	Description	Units	Source
i_{flag}	Flag to indicate which transform to perform 0 = cosine transform 1 = sine transform -1 = deallocates all allocated arrays	N/A	Calling SU
ln_{fft}	Power of 2 transform size, i.e. $n_{fft}=2^{ln_{fft}}$	N/A	FFTPAR SU
x	Field array to be transformed - dimensioned $2^{n_{fft}}$ in calling SU	μV/m	Calling SU

Table 79. DRST output data element requirements.

Name	Description	Units
x	Transform of field	μV/m

5.2.6 Flat-Earth Direct Ray (FEDR) SU

The FEDR SU determines the propagation factor and loss based on FE calculations, for the direct ray path only, for regions above and below the PE maximum propagation angle.

Upon entering the SU the square of the current range, r_{sq}, is initialized to $rsqrd_{i_{stp}}$. Next, the earth curvature height correction factor r_{sqk} is initialized according to the calculation region:

$$r_{sqk} = \frac{r_{sq}}{twoka}; \quad \text{above PE region}$$

$$r_{sqk} = \frac{r_{sq}}{twoka_{down}}; \quad \text{below PE region.}$$

Steps 1 through 2 are performed for all heights within array *zoutma* with index j varying from j_{as} to j_{ae}.

1. First, the direct ray angle is computed as

$$\alpha = \mathbf{TAN}^{-1}\left(\frac{zoutma_j - r_{sqk}}{r_{out}}\right).$$

2. Next, if the direct ray α is greater than the tangent angle α_{ter} produced from the antenna height to the current terrain height, or the calculations are for the upper PE region, then steps 2.a through 2.e are performed.

    a. The ANTPAT SU is referenced to obtain the antenna pattern factor $f(\alpha)$ for the direct ray.

    b. The path length of the direct ray is then computed:

$$r_1 = \sqrt{\left(zoutma_j - r_{sqk}\right)^2 + r_{sq}}\ .$$

    c. The propagation factor (F_{dB}) and loss (L) are then computed from

$$L = 20\,\mathbf{LOG_{10}}\left(r_1\right) + pl_{cnst} - 20\,\mathbf{LOG_{10}}\left(\mathbf{MAX}\left(f\,(\alpha)\mathbf{,}10^{-13}\right)\right) + r_1 gas_{att}$$
$$F_{dB} = 20\,\mathbf{LOG_{10}}\left(r_1\right) + pl_{cnst} - L\,\mathbf{.}$$

    Note that F_{dB} above is actually 20 times the logarithm of the propagation factor F as defined in most text books.

    d. Next, L and F_{dB} are multiplied by 10 and rounded to the nearest integer, then stored in array *mpfl*.

    e. If the propagation factor and angle are to be output (*lang*=‘.true.’), then F_{dB} and α are stored in array *propaf*.

Once the loss has been computed for all heights, the final step is to compute the propagation factor at 1 m above the surface if clutter computations are to be performed (C_{lut} = ‘.true.’). The SU is then exited. Table 80 and Table 81 provide identification, description, units of measure, and the computational source for each FEDR SU input and output data element.

Table 80. FEDR SU input data element requirements.

Name	Description	Units	Source
α_{ter}	Tangent angle from antenna height to terrain height at current range	radians	CALCLOS SU
ant_{ref}	Transmitting antenna height relative to the reference height h_{minter}	meters	TERINIT SU
C_{lut}	Logical flag used to indicate if surface clutter calculations are desired.	N/A	Calling CSCI
gas_{att}	Gaseous absorption attenuation rate	dB/km	GASABS SU
i_{flag}	Flag indicating which portion of the FE region is being computed. 0 = loss is computed for heights above PE region 1 = loss is computed for heights below PE region	N/A	Calling SU
i_{stp}	Current output range step index	N/A	Calling CSCI
j_{ae}	Ending index within *mpfl* of FE loss values	N/A	Calling SU
j_{as}	Starting index within *mpfl* of FE loss values	N/A	Calling SU
lang	Logical flag indicating if propagation angle and propagation factor output is desired.	N/A	Calling CSCI
r_{out}	Current output range	meters	Calling SU
pl_{cnst}	Constant used in determining propagation loss (pl_{cnst} = 20 $\log_{10}(2k_o)$)	dB/m	APMINIT CSC
rsqrd	Array containing the square of all desired output ranges	meters^2	APMINIT CSC
twoka	Twice the effective earth radius	meters	GET_K SU
$twoka_{down}$	Twice the effective earth radius for downward path	meters	GET_K SU
z_c	Height at which to compute the propagation factor for clutter computations. The height is specified with respect to hm_{ref}	meters	APMINIT CSC
zoutma	Array output heights relative to “real” ant_{ref}	meters	APMINIT CSC

Table 81. FEDR SU output data element requirements.

Name	Description	Units
*Fat*1*m*	Propagation factor computed at 1 m above the surface.	dB
mpfl	Array of propagation factor and loss	μV/m
propaf	Two-dimensional array, containing the propagation angles and factors for the direct and reflected rays (where applicable) for all output height/range points	radians,d B

5.2.7 Flat-Earth Model (FEM) SU

The FEM SU computes propagation loss at a specified range based upon FE approximations. The following steps 1 through 11, are performed for each APM height output point j from j_{fs} to j_{fe}.

1. The receiver height at the j^{th} output point, $zout_j$, is first adjusted relative to the antenna height for both the direct and reflected ray paths and is also corrected for earth curvature and average refraction. The receiver heights, z_m and z_p, relative to both the real (direct) and image (reflected) antenna height, respectively, are defined as follows:

$$z_m = zoutma_j - \frac{r_{out}^2}{twoka}$$
$$z_p = zoutpa_j - \frac{r_{out}^2}{twoka}$$

   where $zoutma_j$ and $zoutpa_j$ represent the output height $zout_j$ relative to the “real” and “image” antenna heights, respectively, with respect to mean sea level. *twoka* is twice the effective earth radius as calculated in the FILLHT SU. If the range r_{out} is less than 2.5 km, then z_m and z_p are set equal to $zoutma_j$ and $zoutpa_j$, respectively.

2. Next, the point or range, of reflection, $x_{reflect}$, is given by

$$x_{reflect} = r_{out}\frac{ant_{ref}}{z_p}$$

   This quantity is used when referencing the GETREFCOEF SU.

3. The elevation angles for the direct- and reflected-path rays, α_d and α_r, respectively, are given as

$$\alpha_d = \mathbf{TAN}^{-1}\left(\frac{z_m}{r_{out}}\right)$$
$$\alpha_r = \mathbf{TAN}^{-1}\left(\frac{z_p}{r_{out}}\right)$$

4. The ANTPAT SU is referenced with the direct-path elevation angle to obtain the antenna pattern factor for the direct-path ray, $f(\alpha_d)$; and with the grazing angle (opposite of the reflected-path ray angle) to obtain the antenna pattern factor for the surface-reflected ray, $f(-\alpha_r)$.

5. The path lengths for both the direct-path, r_1, and surface-reflected path, r_2, are computed from simple right triangle calculations, as

$$r_1 = \sqrt{{z_m}^2 + {r_{out}}^2}\ ,$$
$$r_2 = \sqrt{{z_p}^2 + {r_{out}}^2}\ .$$

6. The GETREFCOEF SU is referenced with the reflected-path ray angle to obtain the amplitude, R_{mag}, and phase angle, φ, of the surface-reflection coefficient.

7. From the two path lengths, the surface-reflection phase lag angle, and the free-space wave number, k_o, the total phase angle is determined as

$$\Omega = (r_2 - r_1)k_o + \varphi\ .$$

8. The square of the coherent sum of both the direct-path ray and surface-reflected path ray is computed as

$$f_{sum}^2 = \left| f(\alpha_d)^2 + R_{mag}^2\, f(-\alpha_r)^2 + 2\, f(\alpha_d) R_{mag}\, f(-\alpha_r)\,\mathbf{COS}(\Omega) \right| .$$

9. The propagation factor in decibels, F_{dB}, is computed as

$$F_{dB} = 10\,\mathbf{LOG_{10}}\left[\mathbf{MAX}\left(f_{sum}^2, 10^{-25}\right)\right].$$

   A limit of -250 dB was put on F_{dB} to avoid underflow problems.

10. The propagation factor and loss for the output point $zout_j$ is calculated and rounded to the nearest centibel as

$$mpfl_{1,j} = \mathbf{NINT}\left(10\left(L_{fs} - F_{dB} + r_1 gas_{att}\right)\right)$$
$$mpfl_{2,j} = \mathbf{NINT}\left(10\left(L_{fs} - mpfl_{1,j}\right)\right)$$

   where L_{fs} is the free-space loss term in decibels and is given by

$$L_{fs} = 20\,\mathbf{LOG_{10}}(r_1) + pl_{cnst}\ .$$

11. If the propagation factor and angle are to be output (*lang*=‘.true.’), then α_d, α_r, $f(\alpha_d)$, and $R_{mag} f(\alpha_r)$, in dB, are stored in array *propaf*.

Once the loss has been computed for all heights, the final step is to compute the propagation factor at 1 m above the surface if clutter computations are to be performed (C_{lut} = '.true.'). The propagation factor is computed at height z_c according to steps 1 through 11 above. The SU is then exited.

Table 82 and Table 83 provide identification, description, units of measure, and the computational source for each FEM SU input and output data element.

Table 82. FEM SU input data element requirements.

Name	Description	Units	Source
ant_{ref}	Transmitting antenna height relative to h_{minter}	meters	TERINIT SU
C_{lut}	Logical flag used to indicate if surface clutter calculations are desired.	N/A	Calling CSCI
gas_{att}	Gaseous absorption	dB/m	GASABS SU
ht_{lim}	Maximum height relative to h_{minter}	meters	TERINIT SU
i_{stp}	Current output range step index	N/A	Calling SU
j_{fe}	Ending index within *mpfl* of FE loss values	N/A	Calling SU
j_{fs}	Starting index within *mpfl* of FE loss values	N/A	Calling SU
k_o	Free-space wavenumber	meters^{-1}	APMINIT CSC
lang	Logical flag indicating if propagation angle and propagation factor output is desired.	N/A	Calling CSCI
pl_{cnst}	Constant used in determining propagation loss ($pl_{cnst} = 20 \log_{10}(2k_o)$)	dB/m^2	APMINIT CSC
r_{out}	Current output range	meters	Calling SU
rsqrd	Array containing the square of all desired output ranges	meters^2	APMINIT CSC
twoka	Twice the effective earth's radius	meters	GET_K SU
y_{fref}	Ground elevation height at source	meters	APMINIT CSC
z_c	Height at which to compute the propagation factor for clutter computations. The height is specified with respect to hm_{ref}	meters	APMINIT CSC
zoutma	Array output heights relative to "real" ant_{ref}	meters	APMINIT CSC
zoutpa	Array output heights relative to "image" ant_{ref}	meters	APMINIT CSC

Table 83. FEM SU Output Data Element Requirements.

Name	Description	Units
α_d	Direct path ray angle	radians
$Fat1m$	Propagation factor computed at 1 m above the surface.	dB
mpfl	Propagation factor and loss array	cB
propaf	Two-dimensional array, containing the propagation angles and factors for the direct and reflected rays (where applicable) for all output height/range points	radians,dB

5.2.8 Fast-Fourier Transform (FFT) SU

The FFT SU separates the real and imaginary components of the complex PE field into two real arrays and then references the DRST SU to transform each portion of the PE solution.

For a transform size, n_{fft}, the real and imaginary parts of the complex PE field array U, respectively, are found for the index I from 0 to n_{fft}.:

$$xdum_i = \mathbf{REAL}\left(U_i\right)$$
$$ydum_i = \mathbf{IMAG}\left(U_i\right)$$

The DRST SU is referenced in turn for *xdum* and *ydum* along with ln_{fft}, the power of the transform size to the base 2. The real and imaginary parts of the resulting transform arrays are then converted to the complex array U for i equal 0 to n_{fft} by

$$U_i = \mathbf{CMPLX}\left(xdum_i, ydum_i\right) .$$

Table 84 and Table 85 provide identification, description, units of measure, and the computational source for each FFT SU input and output data element.

Table 84. FFT SU input data element requirements.

Name	Description	Units	Source
ln_{fft}	Power of 2 transform size, i.e. $n_{fft}=2^{ln_{fft}}$	N/A	FFTPAR SU
n_{fft}	Transform size	N/A	FFTPAR SU
U	Complex field to be transformed	μV/m	Calling SU

Table 85. FFT SU output data element requirements.

Name	Description	Units
U	Transform of complex field	μV/m

5.2.9 Free Space Range Step (FRSTP) SU

The FRSTP SU is to propagate the complex PE solution in free space by one range step.

Upon entry the PE field, *farray*, is transformed to p-space (Fourier space) and its array elements are multiplied by corresponding elements in the free space propagator array, *frsp*. Before exiting, the PE field is transformed back to z-space. Both transforms are performed by referencing the FFT SU.

Table 86 and Table 87 provide identification, description, units of measure, and the computational source for each FRSTP SU input and output data element.

Table 86. FRSTP SU input data element requirements.

Name	Description	Units	Source
farray	Field array to be propagated one range step in free space	μV/m	Calling SU
frsp	Complex free space propagator term array	N/A	PEINIT SU
n_{m1}	$n_{fft} - 1$	N/A	PEINIT SU

Table 87. FRSTP SU output data element requirements.

Name	Description	Units
farray	Propagated field array	μV/m

5.2.10 FZLIM SU

The FZLIM SU calculates and stores the outward propagation angle and propagation factor at the top of the PE region for the current PE range. The following steps 1 through 5 are performed for each reference to the FZLIM SU.

1. The FN_GETPFAC function is referenced to determine the propagation factor F_{dB} at height z_{lim}-y_{cur}.

2. If this is the first reference to the FZLIM SU (iz = 1), then the FN_GETPFAC function is referenced to determine the propagation factor, F_{dBlst}, at the previous PE range. A linear interpolation is performed on F_{dB} and F_{dBlst} to compute the propagation factor at range r_{atz} where the XO region begins. The interpolated propagation factor and the outward propagation angle, Fr_{atz} and a_{atz}, respectively, are stored in array *ffacz*. Next, a reference to the SAVEPRO SU is made to store the refractivity profile at the current range from height z_{lim} to the maximum desired output height.

3. A reference is made to the SPECEST SU to determine the outward propagation angle, ϑ_{out}. The counter *iz* is incremented, but is limited to iz_{max}. The propagation factor F_{dB}, current PE range r, and ϑ_{out} (with maximum limit of a_{atz}) are stored in $ffacz_{1,iz}$, $ffacz_{2,iz}$, and $ffacz_{3,iz}$, respectively.

4. If *iz* is greater than 2, then the propagation angle is checked and slightly altered to avoid extreme spiking when using these angles in the XO region. If f_{ter} is '.false.' then the angle stored in *ffacz* is the smaller of ϑ_{out} or the previously stored angle. Now, if

f_{ter} is '.false.', or conversely, if f_{ter} is '.true.' AND *iz* is less than or equal to 10, then the iz^{th} angle stored is adjusted and given by

$$\alpha_{dif} = ffacz_{3,iz} - ffacz_{3,iz-1}$$
$$ffacz_{3,iz} = ffacz_{3,iz-1} \pm \mathbf{MIN}\left(\alpha_{dif}, 10^{-4}\right)$$

where '+' or '-' is used depending on the sign of α_{dif}.

5. Before exiting, a final reference to the SAVEPRO SU is made to store the refractivity profile from height z_{lim} to the maximum desired output height at the current range.

Table 88 and Table 89 provide identification, description, units of measure, and the computational source for each FZLIM SU input and output data element.

Table 88. FZLIM SU input data element requirements.

Name	Description	Units	Source
a_{atz}	Local ray or propagation angle at height z_{lim} and range r_{atz}	radians	APMINIT CSC
Δr_{PE}	PE range step	meters	PEINIT SU
Δz_{PE}	PE mesh height increment (bin width in z-space)	meters	FFTPAR SU
f_{ter}	Logical flag indicating if terrain profile has been specified: .true. = terrain profile specified .false. = terrain profile not specified	N/A	APMINIT CSC
iz	Number of propagation factor, range, angle triplets stored in *ffacz*	N/A	APMINIT CSC FZLIM SU
iz_{max}	Maximum number of points allocated for arrays associated with XO calculations	N/A	APMINIT CSC
r	Current PE range	meters	Calling SU
r_{atz}	Range at which z_{lim} is reached (used for hybrid model)	meters	APMINIT CSC
r_{last}	Previous PE range	meters	Calling SU
r_{log}	10 $\log_{10}$(PE range r)	N/A	PESTEP SU
r_{loglst}	10 $\log_{10}$(previous PE range r_{last})	N/A	PESTEP SU
U	Complex PE field at range r	μV/m	PESTEP SU
$Ulast$	Complex PE field at range r_{last}	μV/m	PESTEP SU
y_{cur}	Height of ground at current range r	meters	PESTEP SU
y_{last}	Height of ground at previous range r_{last}	meters	PESTEP SU
z_{lim}	Height limit for PE calculation region	meters	GETTHMAX SU

Table 89. FZLIM SU output data element requirements.

Name	Description	Units
ffacz	Array containing propagation factor, range, and propagation angle at z_{lim}	dB, meters, radians
iz	Number of propagation factor, range, angle triplets stored in *ffacz*	N/A

5.2.11 Get Propagation Factor (FN_GETPFAC) Function

The FN_GETPFAC function determines the propagation factor at a specified height.

First, linear interpolation is performed on the magnitudes of the PE field at bins k and k+1 to determine the magnitude p_{mag} of the field at the receiver height, z_r :

$$p_{mag} = \left|U_k\right| + f_r \left(\left|U_{k+1}\right| - \left|U_k\right| \right)$$

where the interpolation fraction f_r is determined from

$$f_r = \frac{z_r}{\Delta z_{PE}} - k; \quad k\Delta z_{PE} \le z_r < (k+1)\Delta z_{PE}$$

$$k = \mathbf{INT}\left(\frac{z_r}{\Delta z_{PE}} \right) .$$

p_{mag} is constrained to be not less than 10^{-20} μV/m. Finally, the propagation factor in dB, F_{dB} is given by

$$F_{dB} = 20\,\mathbf{LOG_{10}}\left(\mathbf{MAX}\left(p_{mag}, 10^{-20}\right)\right) + r_{log} .$$

Table 90 and Table 91 provide identification, description, units of measure, and the computational source for each FN_GETPFAC function input and output data element.

Table 90. FN_GETPFAC SU input data element requirements.

Name	Description	Units	Source
Δz_{PE}	PE mesh height increment (bin width in z-space)	meters	Calling SU
r_{log}	10 $\log_{10}$(PE range r)	N/A	Calling SU
U	Complex PE field at range r	μV/m	Calling SU
z_r	Receiver height	meters	Calling SU

Table 91. FN_GETPFAC SU output data element requirements.

Name	Description	Units
F_{dB}	Propagation factor at specified height z_r	dB

5.2.12 Get Reflection Coefficient (GETREFCOEF) SU

The GETREFCOEF SU computes the Fresnel complex reflection coefficient for a given grazing angle, ψ.

Upon entering, the proper dielectric constant nc_i^2 to be applied to the reflected ray must be determined. If the current range is within the FE and RO regions, the FN_DIECON function is referenced to determine the correct nc_i^2 for that range. Otherwise, the value for nc_i^2 is set equal to the current value, nc_{ig}^2 at the PE range. The corresponding dielectric constant nc_i^2 is used in the following equations to compute the reflection coefficient:

$$\Gamma_{0V} = \frac{nc_i^2 \,\mathrm{SIN}(\psi) - \sqrt{nc_i^2 - \mathrm{COS}^2(\psi)}}{nc_i^2 \,\mathrm{SIN}(\psi) + \sqrt{nc_i^2 - \mathrm{COS}^2(\psi)}},$$

$$\Gamma_{0H} = \frac{\mathrm{SIN}(\psi) - \sqrt{nc_i^2 - \mathrm{COS}^2(\psi)}}{\mathrm{SIN}(\psi) + \sqrt{nc_i^2 - \mathrm{COS}^2(\psi)}}$$

where Γ_{0V} and Γ_{0H} represent the reflection coefficients for vertical and horizontal polarization, respectively, and nc_i^2 is computed in the DIEINIT SU and is given by

$$nc_i^2 = \varepsilon_i + j60\sigma_i\lambda\,.$$

ε_i and σ_i are the relative permittivity and conductivity, respectively, to be applied at range $rgrnd_i$, and λ is the wavelength.

If rough surface calculations are required (ruf = '.true.') the Miller-Brown roughness reduction factor is computed. Wind speeds specified by the calling CSCI are allowed to vary with range, therefore the FN_CURWIND function is referenced to obtain the wind speed ω_s at the current range. The sea surface rms wave height is then computed from

$$ruf_{ht} = ruf_{fac}\omega_s^2\,,$$

and the roughness reduction factor ρ is determined by

$$\rho = \left(3.2x_g - 2 + \sqrt{(3.2x_g)^2 - 7x_g + 9} \right)^{-1/2},$$

where

$$x_g = \tfrac{1}{2}\left[ruf_{ht}\ \mathbf{SIN}(\psi) \right]^2 .$$

The final reflection coefficient is then computed as $\Gamma_{V,H} = \rho\Gamma_{0V,0H}$.

Lastly, the magnitude and phase of the complex reflection coefficient are determined from

$$R_{mag} = \left| \Gamma_{V,H} \right|$$
$$\varphi = \mathbf{TAN}^{-1}\left(\frac{\Im(\Gamma_{V,H})}{\Re(\Gamma_{V,H})} \right).$$

Table 92 and Table 93 provide identification, description, units of measure, and the computational source for each GETREFCOEF SU input and output data element.

Table 92. GETREFCOEF SU input data element requirements.

Name	Description	Units	Source
HF_{flag}	HF computation flag indicating the frequency specified is less than 50 MHz	N/A	APMINIT CSC
i_{flag}	Integer flag indicating what region reflection coefficient is being computed 0 = FE and RO regions 1 = PE region	N/A	Calling SU
i_{gr}	Number of different ground types specified	N/A	Calling CSCI
i_{pol}	Polarization flag: 0 = horizontal polarization 1 = vertical polarization	N/A	Calling CSCI
nc^2	Array of complex dielectric constants	N/A	DIEINIT SU
n_w	Number of wind speeds	N/A	Calling CSCI
ψ	Grazing angle	radians	Calling SU
r	Current calculation range	meters	Calling SU
rgrnd	Array containing ranges at which varying ground types apply.	meters	Calling CSCI
rngwind	Ranges of wind speeds entered: $rngwind_I$ = range of i^{th} wind speed	meters	Calling CSCI

Table 92. GETREFCOEF SU input data element requirements. (continued)

Name	Description	Units	Source
ruf	Logical flag indicating if rough sea surface calculations are required '.true.' = perform rough sea surface calculations '.false.' = do not perform rough sea surface calculations	N/A	APMINIT CSC
ruf_{fac}	Factor used for wave height calculation	meters^{-1}	APMINIT CSC
wind	Array of wind speeds	meters/sec	Calling CSCI

Table 93. GETREFCOEF SU output data element requirements.

Name	Description	Units
$\Gamma_{V,H}$	Complex reflection coefficient for vertical (V) and horizontal (H) polarization	N/A
R_{mag}	Magnitude of the reflection coefficient	N/A
φ	Phase of the reflection coefficient	radians

5.2.13 Get Troposcatter Loss (FN_GET_TLOSS) Function

The FN_GET_TLOSS function computes loss due to troposcatter and determine the appropriate loss to add to the already calculated propagation loss at a specific transmitter and receiver point over land and water.

Upon entering the function, *ftloss* is initialized to the propagation loss at the particular receiver height and range, *xloss*. The range from the receiver to the tangent point *d2* is also initialized to that value for smooth surface, *d2se*.

The tangent angle from the receiver, ϑ_2, is initialized to the tangent angle from the particular receiver height over smooth surface, $\vartheta 2se$. However, if f_{ter} = '.true.', then the largest tangent angle a_2 and range d_2 from the receiver to the tangent point are determined using an iterative loop performed for index i from j_{t2}-1 to j_{t1} in decrements of -1 as follows:

$$r_2 = r_{out} - i\,\Delta r_{PE}$$
$$a_2 = \frac{h - tyh_i}{r_2} + \frac{r_2}{twoka},$$

where h is the reciever height.

If the current ϑ_2 value is less than a_2, then ϑ_2 is set equal to a_2 and d_2 is set equal to r_2. The index i is decremented by one and the above calculations are repeated.

Once the above loop is completed, the final value of ϑ_2 is checked. If it is greater than the tangent angle for smooth surface $\vartheta 2se$ (at the same receiver range), then both ϑ_2 and d_2 are set equal to $\vartheta 2se$ and $d2se$, respectively.

Next, if r_{out} is less than the sum of the tangent ranges, d_1 and d_2, then the SU is exited. Otherwise, function program flow continues with the next step.

To account for antenna pattern effects over terrain, the ANTPAT SU is referenced using the tangent angle from the source to determine the antenna pattern factor, $f(\vartheta_1)$. The troposcatter loss term is then adjusted from its smooth surface value as

$$tlst = tlst_s - 20\,\mathbf{LOG}_{10}\left[f\left(\vartheta_1\right)\right].$$

Next, the common volume scattering angle is given by

$$\theta = \vartheta 0_{i_{stp}} - \vartheta_1 - \vartheta_2\,.$$

The following calculations are made to determine the effective scattering height h_o:

$$a = \frac{1}{2}\vartheta 0_{i_{stp}} - \vartheta_1 + \frac{ant_{dif}}{r_{out}},$$
$$b = \frac{1}{2}\vartheta 0_{i_{stp}} - \vartheta_2 - \frac{ant_{dif}}{r_{out}},$$
$$s = \mathbf{MIN}\left(\mathbf{MAX}\left(0.1, \frac{a}{b}\right), 10\right),$$
$$h_o = \frac{s\, r_{out}\theta}{10^3\left(1+s^2\right)}.$$

The parameter η_s is then calculated as a function of h_o:

$$\eta_{sx} = .5696\, h_o\left(1 + sn_1 e^{-3.8\times 10^{-6}\, h_o^6}\right),$$
$$\eta_s = \mathbf{MIN}\left(\mathbf{MAX}\left(.01, \eta_{sx}\right), 5\right).$$

Next, the parameters ct_1 and ct_2 are defined as

$$ct_1 = 16.3 + 13.3\eta_s$$
$$ct_2 = 0.4 + 0.16\eta_s\,,$$

where these are in turn used to calculate the quantities r_1 and r_2:

$$r_1 = \mathbf{MAX}\left(0.1\mathbf{,}\, rt_1\theta\right)\mathbf{,}$$
$$r_2 = \mathbf{MAX}\left(0.1\mathbf{,}\, r_f\ h\,\theta\right)\mathbf{.}$$

The quantity r_f was previously determined by referencing the TROPOINIT SU.

ct_1, ct_2, r_1, and r_2 are next used to determine H_1 and H_2;

$$H_1 = \mathbf{MAX}\left[0\mathbf{,}\, ct_1\left(r_1 + ct_2\right)^{-4/3}\right]\mathbf{,}$$
$$H_2 = \mathbf{MAX}\left[0\mathbf{,}\, ct_1\left(r_2 + ct_2\right)^{-4/3}\right]\mathbf{.}$$

The frequency gain function H_o is then determined by

$$H_o = \frac{H_1 + H_2}{2} + \Delta H_o$$

where

$$\Delta H_o = 6\left[.6 - \mathbf{LOG}_{10}\left(\eta_s\right)\right]\mathbf{LOG}_{10}\left(s\right)\mathbf{LOG}_{10}\left(q_t\right)\mathbf{,}$$
$$q_t = \mathbf{MIN}\left[10\mathbf{,}\, \mathbf{MAX}\left(0.1\mathbf{,}\, \frac{r_2}{s\, r_1}\right)\right]\mathbf{.} \qquad ,$$

ΔH_o is not allowed to be larger than ½(H_1+ H_2) and H_o is set equal to 0 if it becomes negative.

Next, the troposcatter loss is computed from

$$t_{loss} = tlst + 573\theta + rlogo_{i_{stp}} + H_o\ .$$

Finally, through a method of “bold interpolation” the final propagation loss *ftloss*, is adjusted for loss due to troposcatter according to

$$L_{dif} = ftloss - t_{loss}\ \mathbf{,}$$
$$ftloss = t_{loss} \qquad for\ L_{dif} \geq 18\, dB\ ,$$
$$ftloss = ftloss - 10\,\mathbf{LOG}_{10}\left(1 + 10^{0.1 L_{dif}}\right) \quad for\ L_{dif} \geq -18\, dB\ \mathbf{.}$$

Table 94 and Table 95 provide identification, description, units of measure, and the computational source for each FN_GET_TLOSS function input and output data element.

Table 94. FN_GET_TLOSS function input data element requirements.

Name	Description	Units	Source
ant_{dif}	Difference between the transmitter and receiver heights	meters	Calling SU
d1	Range from the transmitter source to the tangent point	meters	Calling SU
d2se	Range from the receiver height to the tangent point over smooth surface	meters	Calling SU
f_{ter}	Logical flag indicating if terrain profile has been specified: '.true.' = terrain profile specified '.false.' = terrain profile not specified	N/A	APMINIT CSC
h	Receiver height at particular range *rout*	meters	Calling SU
i_{stp}	Current output range step index	N/A	Calling SU
jt1	Ending index counter for *tyh* array	N/A	Calling SU
jt2	Starting index counter for *tyh* array	N/A	Calling SU
r_f	Constant used for troposcatter calculations	meters^{-1}	TROPOINIT SU
rlogo	Array containing 20 times the logarithm of all output ranges	N/A	APMINIT CSC
r_{out}	Current output range	meters	Calling SU
rt_1	$r_f * ant_{ref}$	N/A	TROPOINIT SU
sn_1	Surface refractivity term used in troposcatter loss calculation	N/A	Calling SU
$\vartheta 0$	Array of angles used to determine common volume scattering angle	radians	TROPOINIT SU
ϑ_1	Tangent angle from source (for smooth surface)	radians	Calling SU
$\vartheta 2se$	Tangent angle from the receiver height over smooth surface	radians	Calling SU
$tlst_s$	Troposcatter loss term for smooth surface	N/A	Calling SU
twoka	Twice the effective earth radius	meters	GET_K SU
tyh	Adjusted height points of terrain profile at every PE range step.	meters	PEINIT SU
xloss	Propagation loss for receiver height *h* and range r_{out}	dB	Calling SU

Table 95. FN_GET_TLOSS function output data element requirements.

Name	Description	Units
ftloss	Propagation loss with troposcatter	dB

5.2.14 Linear Interpolation (FN_PLINT) Function

This function performs a linear interpolation on parameters pl_1 and pl_2 over a fractional term f_{rac}.

The final interpolated value pl_{int} is determined according to

$$pl_{int} = pl_1 + f_{rac}\left(pl_2 - pl_1\right)$$

and is returned to the calling SU.

Table 96 and Table 97 provide identification, description, units of measure, and the computational source for each FN_PLINT function input and output data element.

Table 96. FN_PLINT function input data element requirements.

Name	Description	Units	Source
f_{rac}	Fractional quantity over which to interpolate	N/A	Calling SU
pl_1	First parameter value	N/A	Calling SU
pl_2	Second parameter value	N/A	Calling SU

Table 97. FN_PLINT function output data element requirements.

Name	Description	Units
pl_{int}	Interpolated parameter	N/A

5.2.15 Mixed Fourier Transform (MIXEDFT) SU

The MIXEDFT SU propagates the PE field in free space one PE range step, applying the Leontovich boundary condition, using the mixed Fourier transform as outlined by Kuttler and Dockery (1991). For finite conducting boundaries (i.e., if vertical polarization is specified or rough surface calculations are required) and the frequency is less than 400 MHz, the central difference form of the DMFT is used. If the frequency is greater than 400 MHz, the backward difference form of the DMFT is used.

Upon entering the SU, the first and last elements of the w array w_0 and $w_{n_{fft}}$ are initialized to 0. If using the central difference form of the DMFT (i_{alg} = 1) the following steps 1 through 6 are performed.

1. The difference field for the vertical PE calculation grid is computed from the PE field as

$$w_i = \frac{U_{i+1} - U_{i-1}}{2\Delta z_{PE}} + \alpha_{h,v} U_i \, ; \qquad i = 1, 2, 3, ..., n_{m1}$$

2. Next, the FRSTP SU is referenced to transform w to p-space, propagate the field forward one PE range step, and is transformed back to z-space upon return.

3. The coefficients used in the central difference form of the mixed transform, c_{k1} and c_{k2}, are propagated to the new range as follows:

$$\begin{aligned} c_{k1} &= c_{k1} \, C_{1x} \\ c_{k2} &= c_{k2} \, C_{2x} \end{aligned} .$$

4. The particular solution ym of Kuttler's difference equation is then computed as follows:

$$\begin{aligned} &ym_i = 2\Delta z_{PE} w_i + R_T w_{i-1} \, ; \qquad i = 1, 2, 3, ..., n_{m1} \\ &ym_0 = 0, \end{aligned}$$

where R_T is a quadratic root as computed in the GETALN SU.

5. The complex PE field U is then determined from

$$\begin{aligned} &U_{n-i} = R_T \left(ym_{n-i} - U_{n-i+1} \right); \qquad i = 1, 2, 3, ..., n_{fft} \\ &U_0 = 0 \end{aligned} .$$

6. The final step in computing the PE field U is

$$U_i = U_i + a_r rn_i + b_r rn_{n-i} \left(-1 \right)^{n-i}; \quad i = 0, 1, 2, ..., n_{fft} \, ,$$

where

$$a_r = ck_1 - R_k \left(\tfrac{1}{2} U_0 + \tfrac{1}{2} U_{n_{fft}} rn_{n_{fft}} + \sum_{i=1}^{n_{fft}-1} U_i rn_i \right),$$

$$b_r = ck_2 - R_k \left(\tfrac{1}{2} U_0 rn_{n_{fft}} + \tfrac{1}{2} U_{n_{fft}} + \sum_{i=1}^{n_{fft}-1} U_{n-i} rn_i \left(-1 \right)^i \right).$$

If using the backward difference form of the DMFT (i_{alg} = 2), then the following steps 1 through 6 are performed.

1. The difference field for the vertical PE calculation grid is computed from the PE field as

$$w_i = U_i - R_T U_{i-1}; \qquad i = 1, 2, 3, ..., n_{m1}$$

2. Next, the FRSTP SU is referenced to transform w to p-space, propagate the field forward one PE range step, and is transformed back to z-space upon return.

3. The coefficient $cmft$ is then propagated forward one range step via

$$cmft = cmft * cmft_x .$$

4. The particular solution of the field U is now computed from

$$U_i = w_i + R_T U_{i-1}; \qquad i = 1, 2, 3, ..., n_{fft}$$
$$U_0 = 0.$$

5. The coefficient a_r for the homogeneous solution is determined as

$$a_r = \frac{cmft - \sum_{i=0}^{n_{fft}-1} U_i rn_i}{\left(\sum_{i=0}^{n_{fft}-1} rn_i^2 \right)} .$$

6. Finally, the PE field U for the backward difference DMFT is computed as the sum of the homogeneous and particular solutions:

$$U_i = U_i + a_r rn_i; \; i = 0, 1, 2, ..., n_{fft} .$$

Table 98 and Table 99 provide identification, description, units of measure, and the computational source for each MIXEDFT SU input and output data element.

Table 98. MIXEDFT SU input data element requirements.

Name	Description	Units	Source
$\alpha_{h,v}$	Surface impedance term for horizontal and vertical polarization	N/A	GETALN SU
C_{1x}	Constant used to propagate c_{k1} by one range step in central difference algorithm	N/A	GETALN SU
C_{2x}	Constant used to propagate c_{k2} by one range step in central difference algorithm	N/A	GETALN SU
ck_1	Coefficient used in central difference form of DMFT	N/A	ALN_INIT SU
ck_2	Coefficient used in central difference form of DMFT	N/A	ALN_INIT SU
$cmft$	Coefficient used in backward difference form of DMFT	N/A	ALN_INIT SU
$cmft_x$	Constant used to propagate $cmft$ by one range step in backward difference algorithm	N/A	GETALN SU
$\Delta z2_{PE}$	Twice the PE mesh height increment (bin width in z-space)	meters	PEINIT SU
i_{alg}	Integer flag indicating which DMFT algorithm is being used: 0 = no DMFT algorithm will be used 1 = use central difference algorithm 2 = use backward difference algorithm	N/A	APMINIT CSC
n_{fft}	Transform size	N/A	FFTPAR SU
n_{m1}	n_{fft}-1	N/A	APMINIT CSC
R_k	Coefficient used in C_1 and C_2 calculations.	N/A	GETALN SU
rn	Array of R_T to the i^{th} power (e.g., $rn_i = R_T^i$)	N/A	GETALN SU
R_T	Complex root of quadratic equation for mixed transform method based on Kuttler's formulation	N/A	GETALN SU
U	Complex field at range r	μV/m	PESTEP SU

Table 99. MIXEDFT SU output data element requirements.

Name	Description	Units
ck_1	Coefficient used in central difference form of DMFT	N/A
ck_2	Coefficient used in central difference form of DMFT	N/A
$cmft$	Coefficient used in backward difference form of DMFT	N/A
U	Complex field at range r	μV/m
w	Difference equation PE field array	μV/m
ym	Field from recursion equation for central difference DMFT	μV/m

5.2.16 Parabolic Equation Step (PESTEP) SU

The PESTEP SU computes propagation loss at a specified range based upon the split-step Fourier PE algorithm.

Upon entering the PESTEP SU, if the current output range step, i_{stp}, is equal to 1, the current PE range r and r_{log} (10 times the logarithm of r) are set equal to zero. The current PE range step i_{PEstp} is also set equal to 0. An iterative DO WHILE loop is then begun to advance the PE solution such that for the current PE range, a PE solution is calculated from the solution at the previous PE range. This iterative procedure is repeated in the DO WHILE loop until r is greater than the output range r_{out}. The following steps (1 through 8) are performed for each PE range step within the DO WHILE loop.

1. First, if the current PE range, r, is greater than zero, then the height of the ground at the previous PE range y_{last} is set to the height of the ground at the current PE range y_{cur}. Next, the previous PE range r_{last} is set equal to the current PE range r. The complex PE field, U, of the previous range is stored in array *Ulast* for subsequent horizontal interpolation at range r_{out}. In addition, r is incremented by one PE range step, Δr_{PE}. A new r_{log} is computed and the PE range step i_{PEstp} is incremented by one. Finally, the range at which interpolation for range-dependent refractivity profiles is performed, r_{mid}, is also incremented by one-half the PE range step.

2. If performing a terrain case (f_{ter} is '.true.'), the ground heights y_{cur} and y_{curm}, at range r and r_{mid}, respectively, must be determined. y_{cur} is set equal to the terrain height at the current PE range step, $tyh_{i_{PEstp}}$. y_{curm} is determined as

$$y_{curm} = \tfrac{1}{2}\left(tyh_{i_{PEstp}-1} + y_{cur}\right).$$

   If y_{cur} is less than y_{last} and the frequency is greater than 50 MHz (HF_{flag}='.false.'), then the DOSHIFT SU is referenced to shift the field accordingly.

3. If the APM CSCI is being used in a range-dependent mode (i.e., the number of profiles n_{prof} is greater than 1), or if a terrain profile is specified, the REFINTER SU is referenced to compute a new modified refractive index profile, *profint*, adjusted by the local ground height y_{curm} at range r_{mid}. If an HF case is being performed and a terrain profile has been specified, then the difference in terrain slopes, tm_{dif}, is computed and a new environmental phase array, *envpr*, is re-computed as

$$envpr_k = e^{i\left(\Delta r_{PE}\, profint_k + k_0 z_k tm_{dif}\right)};\ k=0,1,2,\ldots n_{fft},$$

   Otherwise, *envpr* is computed with the second term in the exponent set equal to 0.

4. The current PE range is then checked against the range of the current ground type given by array *rgrnd*, and if necessary, the ground type counter i_g is incremented. The GETALN SU is then referenced to compute a new surface impedance $\alpha_{h,v}$ if vertical polarization is required or if performing rough surface calculations. If performing an HF case, then a new surface impedance is computed at each PE range step.

5. In order to propagate the field in free space one PE range step the MIXEDFT SU is referenced if the DMFT algorithm is required; otherwise, the FRSTP SU is referenced. The field is then multiplied by the environmental array *envpr*.

6. Next, if the current terrain slope is positive, the DOSHIFT SU is referenced (if not performing an HF case) to shift the field by the appropriate number of bins.

7. If XO calculations are to be performed ($i_{xo} \geq 1$) and the current PE range is greater than r_{atz}, then the FZLIM SU is referenced to determine and store the outward propagation angle at the top of the PE region for subsequent use in the EXTO SU.

8. Finally, after the output range r_{out} is reached and the DO WHILE loop exited, the CALCLOS SU is referenced to obtain the propagation loss values at the desired output heights at the current output range r_{out}.

Table 100 and Table 101 provide identification, description, units of measure, and the computational source for each PESTEP SU input and output data element.

Table 100. PESTEP SU input data element requirements.

Name	Description	Units	Source
Δr_{PE}	PE range step	meters	PEINIT SU
Δr_{PE2}	½ PE range step	meters	PEINIT SU
Ψ	Array of interpolated grazing angles at each PE range step	radians	GRAZE_INT SU
filt	Cosine-tapered (Tukey) filter array	N/A	PEINIT SU
f_{ter}	Logical flag indicating if terrain profile has been specified: .true. = terrain profile specified .false. = terrain profile not specified	N/A	APMINIT CSC
HF_{flag}	HF computation flag indicating the frequency specified is less than 50 MHz	N/A	APMINIT CSC
ht	PE mesh height array of size n_{fft}	meters	PEINIT SU
i_{alg}	Integer flag indicating which DMFT algorithm is being used: 0 = no DMFT algorithm will be used 1 = use central difference algorithm 2 = use backward difference algorithm	N/A	APMINIT CSC

Table 100. PESTEP SU input data element requirements. (continued)

Name	Description	Units	Source
i_g	Counter indicating current ground type being modeled	N/A	APMINIT CSC
i_{gr}	Number of different ground types specified	N/A	Calling CSCI
i_{PE}	Number of PE range steps	N/A	PEINIT SU
i_{PEstp}	Counter indicating current PE range step	N/A	PESTEP SU
i_{pol}	Polarization flag: 0 = horizontal polarization 1 = vertical polarization	N/A	Calling CSCI
i_{stp}	Current output range step index	N/A	Calling SU
i_{xo}	Number of range steps in XO calculation region	N/A	APMINIT CSC
iz	Counter for points stored in $ffacz$	N/A	FZLIM SU
iz_{inc}	Integer increment for storing points at top of PE region (i.e., points are stored at every iz_{inc} range step)	N/A	PEINIT SU
n_{fft}	PE Transform size	N/A	FFTPAR SU
n_{34}	¾ n_{fft}	N/A	PEINIT SU
n_4	¼ n_{fft}	N/A	PEINIT SU
n_{prof}	Number of refractivity profiles	N/A	Calling CSCI
PE_{flag}	Flag to indicate use of PE algorithm only: '.true.' = only use PE sub-model '.false.' = use automatic hybrid model	N/A	Calling CSCI
$profint$	Profile interpolated to every Δz_{PE} in height	M-units	REFINTER SU
r	Current PE range	meters	PESTEP SU
r_{atz}	Range at which z_{lim} is reached (used for hybrid model)	meters	APMINIT CSC
$rgrnd$	Array containing ranges at which varying ground types apply.	meters	Calling CSCI
r_{last}	Previous PE range	meters	PESTEP SU
$rlog$	10 log(PE range r)	N/A	PESTEP SU
r_{max}	Maximum specified range	meters	Calling CSCI
r_{out}	Current output range	meters	Calling SU
ruf	Logical flag indicating if rough sea surface calculations are required '.true.' = perform rough sea surface calculations '.false.' = do not perform rough sea surface calculations	N/A	APMINIT CSC
$tang$	Tangent of angle array from terrain slopes.	radians	PEINIT SU
tyh	Adjusted height points of terrain profile at every PE range step.	meters	PEINIT SU
U	Complex PE field	μV/m	PESTEP SU
y_{cur}	Height of ground at current range r	meters	PESTEP SU

Table 101. PESTEP SU output data element requirements.

Name	Description	Units
envpr	Complex [refractivity] phase term array interpolated every Δz_{PE} in height	N/A
i_g	Counter indicating current ground type being modeled	N/A
i_{PEstp}	Counter indicating current PE range step	N/A
j_{end}	Index at which valid propagation factor and loss values in *mpfl* end	N/A
j_{start}	Index at which valid propagation factor and loss values in *mpfl* begin	N/A
mpfl	Two-dimensional propagation factor and loss array	cB
mpfl_rtg	Propagation loss and factor at receiver heights specified in the *zout_rtg* array	cB
propaf	Two-dimensional array, containing the propagation angles and factors for the direct and reflected rays (where applicable) for all output height/range points	radians, dB
r	Current PE range	meters
r_{last}	Previous PE range	meters
r_{log}	10 log (PE range *r*)	N/A
r_{loglst}	10 log (previous PE range r_{last})	N/A
r_{mid}	Range at which interpolation for range-dependent profiles is performed	meters
U	Complex PE field at range *r*	μV/m
Ulast	Complex PE field at range r_{last}	μV/m
y_{cur}	Height of ground at current range *r*	meters
y_{curm}	Height of ground at range $r+\Delta r_{PE2}$	meters
y_{last}	Height of ground at previous range r_{last}	meters

5.2.17 Ray Trace (RAYTRACE) SU

Using standard ray trace techniques, a ray is traced from a starting height ant_{ref} and range 0, with a specified starting elevation angle, α, to a termination range, x_r. As the ray is being traced, an optical path length difference pl_d (the difference between the actual path length and x_r) and a derivative of range with respect to elevation angle, $dxd\alpha$, are being continuously computed. If the ray should reflect from the surface, a grazing angle, ψ, is determined. Upon reaching the termination range, a terminal elevation angle, β, is determined along with a termination height, z_r.

The raytrace is conducted by stepping in profile levels and computing ending values. A number of stepping scenarios, based upon starting and ending elevation angles, determine the program flow of the RAYTRACE SU. These scenarios are a ray that is upgoing, a ray that is downgoing, and a ray which turns around within a layer.

Upon entering the SU, a running range, x_{sum}, the range at which a ray is reflected, $x_{reflect}$, $dxd\alpha$, pl_d, ψ, and a ray type (direct or reflected) flag, i_{type}, are initialized to zero. A temporary beginning elevation angle, a_{start}, is set equal to α, and an environmental profile

level counter, i, is set equal to the array index for the height in the RO region corresponding to the transmitter height, i_{start}.

The sub-steps within the following steps (1 and 2**)** are now repeated while x_{sum} remains less than the termination range x_r. Upon failure to meet this repetition criterion, the SU program flow continues with step 3 below.

1. The beginning angle a_{start} is examined to determine if the ray is initially upgoing (i.e., $a_{start} \geq 0$) or downgoing. If it is upgoing, the SU program flow continues with steps 1.a through 1.e, otherwise, the program flow continues with step 2 below.

   a. The level counter is examined and if the ray is in the highest layer, (i.e., $i = l_{evels}$), the ending angle, height, range/angle derivative and path length difference are given as

$$\beta = a_{start} + (x_r - x_{sum}) gr_i ,$$

$$z_r = zrt_i + \frac{\beta^{\,2} - a_{start}^2}{2\; gr_i} ,$$

$$dxd\alpha = dxd\alpha + \frac{1}{gr_i}\left(\frac{\alpha}{\beta} - \frac{\alpha}{a_{start}}\right),$$

$$pl_d = pl_d + \frac{1}{gr_i}\left[\left(rm_i - \frac{a_{start}^2}{2}\right)(\beta - a_{start}) + \frac{1}{3}\left(\beta^3 - a_{start}^3\right)\right],$$

   respectively, where *gr* is an intermediate M-unit gradient, *rm* is an intermediate M-unit, and *zrt* is an intermediate height. Satisfaction of this condition causes the failure of the repetition criterion and the SU program flow continues with step 3 below.

   b. If the ray is not in the highest layer, the ray must be examined to determine if it will turn around and become a downgoing ray within the current layer. This is done by looking at the radical term, *rad*, which will be used in the ending angle calculation. The radical term is given as

$$rad = a_{start}^2 + q_{\,i}$$

where q is an intermediate M-unit difference. If rad is greater than or equal to zero, a solution for the ending angle is possible. The ray will not turn around and the program flow continues with step 1.c; otherwise, the program flow continues with step 1.d.

c. Before calculations can continue, the possible ending range must be compared to the termination range. This possible ending range is determined as

$$x_{temp} = x_{sum} + \frac{\beta - a_{start}}{gr_i},$$

$$\beta = \sqrt{rad}.$$

This possible ending range is compared to the termination range and if it is larger, the ending angle, height, range/angle derivative, and path length difference are computed from equations given in step 1.a. Satisfaction of this condition causes the failure of the repetition criterion and the SU program flow continues with step 3 below.

If the ray has not reached the termination range, x_{sum} is updated to x_{temp} ; the range/angle derivative and path length difference are computed from equations given in step 1.a, where $\beta = \sqrt{rad}$; a_{start} is updated to β; the level counter is incremented by one; and the program flow returns to step 1 above.

d. If the ray has, in fact, turned around within the current layer, a determination must be made for the ray reaching a full range step within the still upgoing segment, for the ray reaching a full range step within the downgoing segment, or the ray exceeding the termination range. The full range step is given by

$$x_{temp} = x_{sum} - \frac{a_{start}}{gr_i},$$

which is compared to the termination range. If it exceeds the termination range, the ending angle, the ending height, the range/angle derivative, and the path length difference are determined from equations given in step 1.a. Satisfaction of this condition causes the failure of the repetition criterion and the SU program flow continues with step 3 below. If the termination range has not been exceeded, further examination of the ray's segments must be made.

e. At this point, x_{sum} is updated to x_{temp}; x_{temp} is recalculated as shown in step 1.d; and x_{temp} is again compared to the termination range.

If the termination range has been exceeded, the ending angle is given as

$$\beta = (x_r - x_{sum}) gr_i ,$$

and the ending height, the range/angle derivative, and the path length difference are now determined from equations shown in step 1.a. Satisfaction of this condition causes the failure of the repetition criterion and the SU program flow continues with step 3 below.

If the termination range has not been exceeded, x_{sum} is updated to x_{temp}; β is updated to $-a_{start}$; the range/angle derivative and path length difference are determined from equations shown in step 1.a; a_{start} is updated to β; and the program flow returns to step 1 above.

2. **Note!** The equations for the upgoing ray within step 1 above apply equally to the downgoing ray except where specified, otherwise. However, in applying these equations to step 2, the level counter, *i*, within the intermediate M-unit gradient sub-term, *gr*, must be reduced by one.

   The beginning angle a_{start} has been examined in step 1 above and the ray has been determined to be initially downgoing. Similar to step 1 above, the ray must be examined to determine if it has turned around and has become an upgoing ray within the current layer. This is done by looking at the radical term, *rad,* which will be used in the ending angle calculation. This radical term is given as

$$rad = a_{start}^2 - q_{i-1} .$$

   If *rad* is greater than or equal to zero, a solution for the ending angle is possible. The ray has not turned around and the program flow continues with steps 2.a through 2.c below; otherwise, the program flow continues with step 2.d.

   a. Before calculations can continue, the possible ending range must be compared to the termination range. This possible ending range is determined from the equation given for x_{temp} in step 1.c, where β is now $-\sqrt{rad}$. This possible ending range is compared to the termination range and if it is larger, the ending angle, the ending height, the range/angle derivative, and the path length difference are computed from equations shown in step 1.a. Satisfaction of this condition causes the failure of the repetition criterion and the SU program flow continues with step 3 below.

b. If the termination range has not been exceeded, x_{sum} is updated to x_{temp}; the range/angle derivative and path length difference are computed as shown in step 1.a, where $\beta = -\sqrt{rad}$; a_{start} is updated to β; and the level counter is decremented by one.

c. The level counter is examined and if it is zero, the ray has reflected from the surface. In this case, the ray type flag is set to 1 to indicate a reflection, the grazing angle is set as $\psi = |a_{start}|$, and $x_{reflect}$ is set equal to x_{temp}. At this point a symmetry check is made. The idea of symmetry says that the ray will return to its starting height, at twice the reflection range, with an ending elevation angle opposite the starting elevation angle. Symmetry is used for APM speed efficiency so as to preclude redundant ray trace calculations on the upward path back to the starting height. Prior to applying symmetry however, the possible ending range (twice x_{sum}) must be compared to the termination range. If the termination range is exceeded by making the symmetry assumption, a_{start} is updated to $-a_{start}$ and the assumption is vacated. If not however, the assumption is invoked and a_{start} is updated to $-\alpha$; x_{sum} , $dxd\alpha$, and pl_d, are doubled; and the level counter is restored to i_{start}. Control is now returned to the top of step 1 above.

d. From step 2, the ray has turned around within the current layer and is now an upgoing ray. Similar to the upgoing case of step 1, a determination must be made for the ray reaching a full range step within the still downgoing segment, for the ray reaching a full range step within the upgoing segment, or the ray exceeding the termination range. The full range step is given by x_{temp} as computed step 1.d.

   If the full range step exceeds the termination range, the ending angle, the ending height, the range/angle derivative, and the path length difference are computed from equations shown in step 1.a. Satisfaction of this condition causes the failure of the repetition criterion and the SU program flow continues with section 3 below. If the termination range has not been exceeded, further examination of the ray's segments must be made.

e. At this point, x_{sum} is updated to x_{temp}; x_{temp} is recalculated as in step 1.d, and x_{temp} is again compared to the termination range. If the termination range has been exceeded, the ending angle is determined as in step 1.e; the ending height, range/angle derivative, and path length difference are determined as in step 1.a. Satisfaction of this condition causes the failure of the repetition criterion and the SU program flow continues with step 3 below.

   If the termination range has not been exceeded, x_{sum} is updated to x_{temp}; β is updated to $-a_{start}$; the range/angle derivative and path length difference are determined as in step 1.a; a_{start} is updated to β; and the program flow returns to step 1 above.

3. Within APM, the terminal elevation angle is not allowed to be equal to zero. Therefore, if its absolute value is less than 10^{-10}, it is reset to 10^{-10} while retaining its present sign.

Table 102 and Table 103 provide identification, description, units of measure, and the computational source for each RAYTRACE SU input and output data element.

Table 102. RAYTRACE SU input data element requirements.

Name	Description	Units	Source
α	Source elevation angle	radians	Calling SU
gr	Intermediate M-unit gradient array, RO region	(M-unit/m)10^{-6}	REFINIT SU
i_{start}	Array index for height in RO region corresponding to ant_{ref}	N/A	REFINIT SU
$levels$	Number of levels in gr, q and zrt arrays	N/A	REFINIT SU
q	Intermediate M-unit difference array, RO region	2(M-unit)10^{-6}	REFINIT SU
rm	Intermediate M-unit array, RO region	M-unit 10^{-6}	REFINIT SU
x_r	Terminal range - called x_{ROn} in ROCALC SU, equivalent to r_{out} in calling SU	meters	Calling SU
zrt	Intermediate height array, RO region	meters	REFINIT SU

Table 103. RAYTRACE SU output data element requirements.

Name	Description	Units
β	Terminal elevation angle	radians
$dxd\alpha$	Derivative of range with respect to elevation angle	meters/radians
i_{type}	Ray type (direct or reflected) flag	N/A
pl_d	Path length from range x_r	meters
ψ	Grazing angle	radians
$x_{reflect}$	Range at which ray is reflected	meters
z_r	Terminal height	meters

5.2.18 Refractivity Interpolation (REFINTER) SU

The REFINTER SU interpolates horizontally and vertically on the modified refractivity profiles. Profiles are then adjusted so they are relative to the local ground height .

Upon entry, the number of height/refractivity levels , *lvlep*, for the current profile is set equal to the user-specified number of levels for all profiles specified, *lvlp*. For the range-dependent case, all profiles have the same number of levels.

If there is a range-dependent environment (i.e., $n_{prof} > 1$), horizontal interpolation to range r_{ange} is performed between the two neighboring profiles that are specified relative to mean sea level. In this case the following calculations are made. If r_{ange} is greater than the range for the next refractivity profile rv_2, then the index j (indicating the range of the previous refractivity profile) is set equal to the counter for the range of the current profile i_s; i_s is then incremented by one. Next, the range of the previous refractivity profile rv_1 is set equal to rv_2, and rv_2 is set equal to the range of the i_s^{th} profile, $rngprof_{i_s}$. The fractional range fv for the interpolation is given by

$$fv = \frac{r_{ange} - rv_1}{rv_2 - rv_1} \ .$$

The array *refdum,* containing M-unit values for the current (interpolated) profile and the array *htdum* containing height values for the current (interpolated) profile are determined from referencing the FN_PLINT function:

$$\begin{aligned} refdum_i &= \mathbf{FN\_PLINT}\left(refmsl_{i,j}, refmsl_{i,i_s}, fv\right); i = 1, 2, 3, \ldots lvlep \\ htdum_i &= \mathbf{FN\_PLINT}\left(hmsl_{i,j}, hmsl_{i,i_s}, fv\right); i = 1, 2, 3, \ldots lvlep \end{aligned} \ ,$$

where *refmsl* and *hmsl* are Two-dimensional arrays containing refractivity and height, respectively, with respect to mean sea level of each user-specified profile.

The REMDUP SU is referenced to remove duplicate refractivity levels, with *lvlep* being the number of points in the profile at range r_{ange}. The PROFREF SU is then referenced to adjust the new profile (i.e., *refdum* and *htdum*) relative to the internal reference height h_{minter}, corresponding to the minimum height of the terrain profile. The PROFREF SU is then referenced once more to adjust the profile relative to the local ground height y_{curm}, and upon exit from the PROFREF SU, the INTPROF SU is referenced to interpolate vertically on the refractivity profile at each PE mesh height point. This results in the n_{fft}-point profile array *profint* containing the interpolated M-unit values for the refractivity at r_{ange}, where n_{fft} is the transform size.

Upon exiting the REFINTER SU, rv_1 and index j are saved for use upon the next reference of the SU.

Table 104 and Table 105 provide identification, description, units of measure, and the computational source for each REFINTER SU input and output data element.

Table 104. REFINTER SU input data element requirements.

Name	Description	Units	Source
f_{ter}	Logical flag indicating if terrain profile has been specified: .true. = terrain profile specified .false. = terrain profile not specified	N/A	APMINIT CSC
h_{minter}	Minimum height of terrain profile	meters	TERINIT SU
hmsl	Two-dimensional array containing heights with respect to mean sea level of each profile. Array format must be $hmsl_{i,j}$ = height of i^{th} level of j^{th} profile. j=1 for range-independent cases	meters	Calling CSCI
i_s	Counter for current profile	N/A	REFINIT SU REFINTER SU
i_{stp}	Current output range step index	N/A	Calling SU
lvlp	Number of height/refractivity levels in profiles	N/A	Calling CSCI
n_{prof}	Number of refractivity profiles	N/A	Calling CSCI
r_{ange}	Range for profile interpolation	meters	Calling SU
refmsl	Two-dimensional array containing refractivity with respect to mean sea level of each profile. Array format must be $refmsl_{i,j}$ = M-unit at i^{th} level of j^{th} profile. j=1 for range-independent cases	M-unit	Calling CSCI
rngprof	Ranges of each profile. $rngprof_i$ = range of i^{th} profile	meters	Calling CSCI
rv_2	Range of the next refractivity profile	meters	REFINIT SU REFINTER SU
y_{curm}	Height of ground midway between last and current PE range	meters	PESTEP SU

Table 105. REFINTER SU output data element requirements.

Name	Description	Units
htdum	Height array for current interpolated profile	meters
i_s	Counter for current profile	N/A
lvlep	Number of height/refractivity levels in profile *refdum* and *htdum*	N/A
profint	Profile interpolated to every Δz_{PE} in height	M-units
refdum	M-unit array for current interpolated profile	M-units
rv_2	Range of the next refractivity profile	meters

5.2.19 Ray Optics Calculation (ROCALC) SU

The ROCALC SU computes the RO components which will be needed (by the ROLOSS SU) in the calculation of propagation loss at a specified range and height within the RO region. These components are the magnitudes for a direct-path and surface-reflected ray, Fd^2 and Fr^2, respectively, and the total phase lag angle, Ω, between the direct-path and surface-reflected rays.

The RO region may be visualized as having a grid of points superimposed upon it. The grid points are defined at the intersection of a series of lines sloping upward from the origin and a series of vertical lines at varying ranges. The grid point counter k and the vertical lines are defined at varying ranges, two of which are represented by the terms x_{ROp}, a range for which the RO calculations were previously performed, and x_{ROn}, the next calculation range.

The sloping line with the greatest angle (indicated by $k = k_{max}$) is a function of the maximum APM output height, ht_{ydif}, adjusted for terrain and reference heights, and the next calculation range. The sloping line with the least angle (indicated by $k = k_{minp}$) is a function of the height at the top of the PE region and the range of the previous RO calculations.

The following steps 1 through 4 are performed while the current range, x, is greater than x_{ROn}.

1. The terms of Table 106 (defined in Table 107) are initialized or updated based upon the RO calculation range counter i_{ROp}. If i_{ROp} equals -1, the terms are initialized; otherwise, the terms are updated. Note that the terms must be computed in the order they appear in the table to insure proper values are assigned to component terms.

Table 106. RO region indices, angles, and ranges.

For $iROp$ = -1 (initialize terms)	For $iROp \neq$ -1 (update terms)
$i_{ROp} = 1$	$i_{ROp} = 1 - i_{ROp}$
$i_{ROn} = 0$	$i_{ROn} = 1 - i_{ROn}$
N/A	$x_{ROp} = x_{ROn}$
$k_{minp} = 0$	$k_{minp} = k_{minn}$
$k_{minn} = 0$	$k_{minn} = 0$
$ht_{ydif} = ht_{lim} - y_{fref}$	**N/A**
$d\alpha = \mathbf{MIN}\left(\frac{\mu_{bwr}}{2}, .01745\right)$	**N/A**
$k_{max} = 88$	$k_{max} = \mathbf{MIN}\left(88, \mathbf{INT}\left(\frac{1000\, ht_{ydif}}{x_{ROp}}\right) + 2\right)$

Table 106. RO region indices, angles, and ranges. (continued)

For $iROp$ = -1 (initialize terms)	For $iROp \neq$ -1 (update terms)
$frac_{RO} = 0$	$frac_{RO} = \left(\mathbf{MAX}\left(\frac{.001 k_{max}}{d\alpha}, 5 \right) - 1 \right)^{-1}$; for $frac_{RO} < .25$
N/A	$\Delta x_{RO} = frac_{RO} \; x_{ROp}$
$x_{ROn} = x$	$x_{ROn} = x_{ROp} + \Delta x_{RO}$

2. To calculate the RO components at each vertical point for the next range, x_{ROn}, a ray trace within a Newton iteration method is used to find a direct-path ray and a surface-reflected ray which will both originate at the transmitter height, ant_{ref}, and terminate at the same grid point, z_k. The results of the iteration are examined and if either of the rays has not been found, an adjustment in the lower boundary of the RO region is made. Following the conclusion of the iterations, the antenna pattern factors for each ray are obtained, a surface reflection coefficient for the surface-reflected ray is computed, and the RO components are calculated.

   Prior to all calculations for each vertical point, the ray trace must be initialized with beginning direct-path and surface-reflected ray elevation angles, α_d and α_r, respectively; and derivatives of height with respect to these elevation angles, $dzd\alpha_d$ and $dzd\alpha_r$. A starting assumption is made that the direct-path ray and the surface-reflected rays are parallel to each other. Thus, α_d is initialized as 0.001 k_{max} and α_r is initialized as -α_d . The RAYTRACE SU is referenced separately with α_d and α_r to obtain termination elevation angles, β_d and β_r, and the two derivatives of range with respect to elevation angle, $dxd\alpha_d$ and $dxd\alpha_r$, which are used in turn to compute the needed derivatives of height with respect to elevation angle given as -$\beta_d \; dxd\alpha_d$ and -$\beta_r \; dxd\alpha_r$.

3. Once the raytrace has been initialized, the following steps 3.a through 3.g are performed for each vertical grid point, z_k, beginning with $k = k_{max}$ and subsequently decrementing k downward while k remains $\geq k_{minn}$. Once k has reached zero, processing continues with step 4 below.

   a. The termination height is computed as

$$z_k = x_{ROn} \; 0.001 \, k$$

   where k is the grid point counter.

b. The Newton iteration method to find the direct path ray from ant_{ref} to z_k is started. This iteration is continued until the difference between the ray trace ending height z_d and z_k is less than a height difference tolerance z_{tol}; but in any case, no more than 10 times. The direct-path elevation angle is given as

$$\alpha_d = \alpha_d - \frac{z_d - z_k}{dzd\alpha_d}$$

where z_d and $dzd\alpha_d$ are obtained from the ray trace initialization of step 2 above for the first iteration and from the previous iteration for subsequent iterations.

The RAYTRACE SU is referenced and a new $dzd\alpha_d$ is calculated as $-\beta_d\ dxd\alpha_d$. This new $dzd\alpha_d$ is examined and if it is less than 10^{-6}, or if the ray type flag i_{type} , returned from the RAYTRACE SU, indicates the ray has reflected, the lower boundary of the RO region is adjusted by setting k_{minn} equal to one more than k and the iteration for the direct ray is stopped.

c. The Newton iteration method to find the surface-reflected ray from ant_{ref} to z_k is now started. This iteration should be continued until the difference between the ray trace ending height, z_r and z_k is less than a height difference tolerance z_{tol}; but in any case, no more than 10 times. The reflected-path elevation angle is given as

$$\alpha_r = \alpha_r - \frac{z_r - z_k}{dzd\alpha_r}$$

where z_r and $dzd\alpha_r$ are obtained from the ray trace initialization of step 2 above for the first iteration and from the previous iteration for subsequent iterations.

The RAYTRACE SU is referenced and a new $dzd\alpha_r$ is calculated as $-\beta_r\ dxd\alpha_r$. This new $dzd\alpha_r$ is examined and if it is less than 10^{-6}, or if i_{type} indicates the ray is a direct ray, the lower boundary of the RO region is adjusted by setting k_{minn} equal to one more than k and the iteration for the surface-reflected ray is stopped.

d. A test is made to determine if the grazing angle, ψ, (returned from the RAYTRACE SU) is less than the limiting value, ψ_{lim}, and if so, the lower boundary of the RO region is adjusted by setting k_{minn} equal to k.

e. The magnitudes for the direct-path and surface-reflected ray, Fd^2 and Fr^2 respectively, are now given as

$$Fd^2 = \left| \frac{x_{ROn}}{dzd\alpha_d} \right| f^2(\alpha_d),$$

$$Fr^2 = \left| \frac{x_{ROn}}{dzd\alpha_r} \right| \left[f(\alpha_r) R_{mag} \right]^2,$$

where the amplitude of the surface reflection coefficient, R_{mag}, is obtained from a reference to the GETREFCOEF SU; the antenna pattern factors $f(\alpha_d)$ and $f(\alpha_r)$ are obtained from references to the ANTPAT SU; and the derivatives of height with respect to elevation angle are obtained from the RAYTRACE SU within the Newton iteration of steps 3.b and 3.c above.

f. The total phase lag between the direct-path and surface-reflected rays is computed as

$$\Omega = (pl_r - pl_d)k_o + \varphi,$$

where the ray path lengths pl_d and pl_r are obtained from the RAYTRACE SU within the Newton iteration of steps 3.b and 3.c above; the reflection coefficient phase lag angle, φ, is obtained from a reference to the GETREFCOEF SU; and k_o is the free-space wave number.

g. If the propagation angles and factors are to be computed for each separate ray (*lang* = '.true.'), then the current propagation angles for the direct and reflected rays, β_d and β_r respectively, are stored in arrays $RO\alpha_{dir}$ and $RO\alpha_{ref}$.

4. If the point counter *k* has been reduced to zero by the procedures of steps 3.a through 3.g above, the surface values of magnitudes for the direct-path and surface-reflected rays are both set equal to the last value of Fd^2 and the total phase lag between the direct-path and surface-reflected rays is set equal to $-\pi$. If vertical polarization has been specified, then a further calculation is performed for the special case when the RO output height is less than 0 due to the height adjustment of y_{fref}. A FE calculation is made at this lowest height and replaces the previous values of magnitudes for the direct and surface-reflected paths, along with a new phase lag.

Table 107 and Table 108 provide identification, description, units of measure, and the computational source for each ROCALC SU input and output data element.

Table 107. ROCALC SU input data element requirements.

Name	Description	Units	Source
ant_{ref}	Transmitting antenna height relative to the reference height h_{minter}	meters	TERINIT SU
μ_{bwr}	Antenna vertical beamwidth	radians	Calling CSCI
$d\alpha$	½ μ_{bwr}	radians	ROCALC SU
$frac_{RO}$	RO range interval fraction (0.0 to 0.25)	N/A	ROCALC SU
ht_{lim}	Maximum height relative to h_{minter}	meters	TERINIT SU
ht_{ydif}	$ht_{lim} - y_{fref}$	meters	ROCALC SU
i_{pol}	Polarization flag: 0 = horizontal polarization 1 = vertical polarization	N/A	Calling CSCI
i_{ROn}	Array index for next range in RO region	N/A	ROCALC SU
i_{ROp}	Array index for previous range in RO region	N/A	APMINIT CSC ROCALC SU
k_o	Free-space wave number	meters^{-1}	APMINIT CSC
k_{minn}	Array index for minimum angle in RO region at range x_{ROn}	N/A	ROCALC SU
$lang$	Propagation angle and factor output flag '.true.'= Output propagation angle and propagation factor for direct and reflected ray (where applicable). '.false.' = Do not output propagation angles and factors	N/A	Calling CSCI
ψ_{lim}	Grazing angle of limiting ray	radians	APMINIT CSC
$twoka$	Twice the effective earth radius	meters	GET_K SU
x	Current range	meters	Calling SU
x_{ROn}	Next range in RO region	meters	APMINIT CSC
x_{ROp}	Previous range in RO region	meters	ROCALC SU
y_{fref}	Ground elevation height at source	meters	APMINIT CSC
$zoutma$	Array output heights relative to "real" ant_{ref}	meters	APMINIT CSC
$zoutpa$	Array output heights relative to "image" ant_{ref}	meters	APMINIT CSC
zro	Array of output heights	meters	APMINIT CSC
z_{tol}	Height tolerance for Newton's method	meters	APMINIT CSC

Table 108. ROCALC SU output data element requirements.

Name	Description	Units
$d\alpha$	½ μ_{bwr}	radians
Δx_{RO}	RO range interval	meters
Fd^2	Magnitude array, direct ray	N/A
Fr^2	Magnitude array, reflected ray	N/A

Table 108. ROCALC SU output data element requirements. (continued)

Name	Description	Units
$frac_{RO}$	RO range interval fraction (0.0 to 0.25)	N/A
ht_{ydif}	ht_{lim} - y_{fref}	meters
i_{ROn}	Array index for next range in RO region	N/A
i_{ROp}	Array index for previous range in RO region	N/A
k_{max}	Array index for maximum angle in RO region at range x_{ROn}	N/A
k_{minn}	Array index for minimum angle in RO region at range x_{ROn}	N/A
k_{minp}	Array index for minimum angle in RO region at range x_{ROp}	N/A
Ω	Total phase angle array	radian
$RO\alpha_{dir}$	Array of propagation angles for direct rays	radians
$RO\alpha_{ref}$	Array of propagation angles for reflected rays	radians
x_{ROn}	Next range in RO region	meters
x_{ROp}	Previous range in RO region	meters

5.2.20 Ray Optics Loss (ROLOSS) SU

The ROLOSS SU calculates propagation factor and loss values at all valid RO heights at a specified range based upon the components of magnitude for a direct-path and surface-reflected ray, Fd^2 and Fr^2 respectively, and the total phase lag angle, Ω, between the two rays as determined by the ROCALC SU.

Upon entering the SU, the ROCALC SU is referenced to obtain the current values of the direct and reflected ray magnitudes, along with the phase lag for all heights at the specified range r_{out}.

For computational efficiency, an interpolation from the magnitude and total phase lag angle arrays established by the ROCALC SU is made to obtain these three quantities at each APM vertical output mesh point within the RO region.

From the interpolated phase lag angle and ray magnitudes, a propagation factor is calculated that is used in turn with the free-space propagation loss to obtain a propagation loss at each vertical APM output point.

A range ratio term to be used within the interpolation scheme is defined as

$$ratio = \frac{r_{out} - x_{ROp}}{\Delta x_{RO}} .$$

The phase lag angle and ray magnitude arrays have been filled at grid points defined by a series of sloping lines and the next and previous RO calculation range, x_{ROn}

and x_{ROp}, respectively. Which values to interpolate from are determined by the sloping line immediately above and the sloping line immediately below the current APM output point of interest. To begin the calculations k_{lo} is initialized to k_{max}, the line with the greatest angle.

Perform steps 1 through 6, decrementing downward in APM output points from the maximum output height index in the RO region, j_{max}, to the minimum output height index, in the RO region, j_{min}-1, where the index j varies from j_{max} to j_{min}-1.

1. Interpolation of Fd^2, Fr^2, and Ω values occurs in two stages. The first stage is horizontally, above and below the APM output point (i.e., along the lines k_{lo} and k_{hi}). These values will be used in turn, in a vertical interpolation stage to obtain values at the APM output point itself. It may be however, that more than one APM output point will fall between two adjacent k lines. In this case, it would be redundant to perform the horizontal interpolation more than once. For this reason, a temporary k line counter is established that will be used in comparison with k_{lo} to determine if interpolation is necessary or if the previously interpolated horizontal values may again be used in the vertical interpolation. This temporary k counter is given by

$$k_{temp} = \mathbf{INT}\left(\frac{1000\, zro_j}{r_{out}}\right),$$

   where j is the APM output point counter, and zro_j is the j^{th} output height point . If the index j has already reached the lowest value of j_{min}-1 and clutter calculations are to be performed, then the height at which to compute the propagation factor is replaced with z_c, a height of 1 m above the surface, which is done by replacing zro_j above with the adjusted height z_c-y_{fref}. If k_{temp} is less than the current k_{lo}, the APM output point occurs below the current lower k line and horizontal interpolations must be performed using steps 1.a through 1.c; otherwise, the horizontal interpolations are unnecessary and the SU may proceed with step 2.

   a. The lower k line, k_{lo}, is reset to k_{temp} and the upper k line, k_{hi}, is set to one more than k_{lo}.

   b. In preparation for the interpolation, component terms (horizontal differences of direct and surface-reflected magnitudes and phase lag angles) along the k_{lo} and k_{hi} lines are given as

$$\Delta Fd_{lo}^2 = Fd^2_{i_{ROn},k_{lo}} - Fd^2_{i_{ROp},k_{lo}},$$
$$\Delta Fr_{lo}^2 = Fr^2_{i_{ROn},k_{lo}} - Fr^2_{i_{ROp},k_{lo}},$$
$$\Delta\Omega_{lo} = \Omega_{i_{ROn},k_{lo}} - \Omega_{i_{ROp},k_{lo}},$$

and similarly, the propagation angles for the direct and reflected rays are given as

$$\begin{aligned}\Delta\alpha d_{lo} &= RO\alpha_{dir(i_{ROn},klo)} - RO\alpha_{dir(i_{ROp},klo)}\\ \Delta\alpha r_{lo} &= RO\alpha_{ref(i_{ROn},klo)} - RO\alpha_{ref(i_{ROp},klo)}\end{aligned},$$

if *lang* = '.true.', substituting the index k_{hi} for k_{lo} as appropriate. Note that these horizontal differences need only be calculated while k_{hi} and k_{lo} remain greater than or equal to k_{minp} and k_{minn} . If these conditions are not met, any continued difference calculations would take place within the PE region, which would yield undesirable results. For failure of these conditions, the previously calculated difference values are used for the lower RO region boundary calculations.

c. If k_{lo} is greater than or equal to k_{minp} , the horizontally interpolated direct and surface-reflected magnitudes and phase lag angles along the k_{lo} line can proceed in a forward manor (from x_{ROp} to r_{out}). These values are given as

$$\begin{aligned}Fd_{lo}^2 &= Fd_{i_{ROp},k_{lo}}^2 + ratio\ \Delta Fd_{lo}^2,\\ Fr_{lo}^2 &= Fr_{i_{ROp},k_{lo}}^2 + ratio\ \Delta Fr_{lo}^2,\\ \Omega_{lo} &= \Omega_{i_{ROp},k_{lo}} + ratio\ \Delta\Omega_{lo},\\ \alpha d_{lo} &= RO\alpha_{dir\left(i_{ROp},k_{lo}\right)} + ratio\ \Delta\alpha d_{lo},\\ \alpha r_{lo} &= RO\alpha_{ref\left(i_{ROp},k_{lo}\right)} + ratio\ \Delta\alpha r_{lo}.\end{aligned} \qquad \text{if } lang = .\text{'true.'}.$$

In a like manor, the same equations above are used to get the values along the k_{hi} line by substituting the index k_{hi}, assuming, however, k_{hi} is also greater than or equal to k_{minp}. Should k_{lo} or k_{hi} be less than k_{minp}, the interpolation must proceed in a backward manner (from x_{ROn} to r_{out}). The above equations may again be used by substituting the index i_{ROn} for i_{ROp} and the value (1 - *ratio*) for *ratio.*

2. Once the horizontal interpolation of magnitudes and phase lag angles has been accomplished, the vertical interpolation of magnitudes and phase lag angles at the APM output point may proceed as

$$\begin{aligned}Fd^2 &= Fd_{lo}^2 + ratio_k\left(Fd_{hi}^2 - Fd_{lo}^2\right),\\ Fr^2 &= Fr_{lo}^2 + ratio_k\left(Fr_{hi}^2 - Fr_{lo}^2\right),\\ \Omega &= \Omega_{lo} + ratio_k\left(\Omega_{hi} - \Omega_{lo}\right),\end{aligned}$$

and again, if separate values for the direct and reflected rays are desired (*lang* = '.true.'), these are given by

$$\alpha_{dir} = \alpha d_{lo} + ratio_k \left(\alpha d_{hi} - \alpha d_{lo}\right),$$
$$\alpha_{ref} = \alpha r_{lo} + ratio_k \left(\alpha r_{hi} - \alpha r_{lo}\right).$$

Where $ratio_k$ from k_{lo} to k_{hi} is

$$ratio_k = \frac{1000\, zro_j}{r_{out}} - k_{lo}\,.$$

3. From the magnitudes of the direct and surface-reflected components and the phase lag angle, the square of the propagation factor at the APM output point is given as

$$F^2 = \left|\ Fd^2 + Fr^2 + 2\sqrt{\left|Fd^2 Fr^2\right| \mathbf{COS}\,\Omega}\ \right|,$$

which in turn is converted to a propagation factor expressed in decibels by

$$F_{dB} = 10\,\mathbf{LOG}_{10}\left[\mathbf{MAX}\left(F^2\mathbf{,}10^{-25}\right)\right].$$

4. Next, if clutter calculations are to be performed and the *j* index has reached its lowest value, then the propagation factor is stored in the array *ffat1m*.

5. The total propagation loss and propagation factor is then computed at the j^{th} APM output point and converted to centibels according to

$$L_{dB} = fsl_{i_{stp}} - F_{dB} + gas_{loss}\,,$$
$$F_{dB} = fsl_{i_{stp}} - L_{dB}\,,$$
$$mpfl_{1,j} = \mathrm{NINT}\left(10\,L_{dB}\right),$$
$$mpfl_{2,j} = \mathrm{NINT}\left(10\,F_{dB}\right),$$

where $fsl_{i_{stp}}$ is the free space loss at the i_{stp}^{th} output range.

6. Lastly, if the propagation angles and factors for the direct and reflected rays are desired, these are stored separately according to

$$propaf_{1,j} = \alpha_{dir},$$
$$propaf_{2,j} = 10\,\mathrm{LOG}_{10}\left(Fd^2\right),$$
$$propaf_{3,j} = \alpha_{ref},$$
$$propaf_{4,j} = 10\,\mathrm{LOG}_{10}\left(Fr^2\right),$$

Table 109 and Table 110 provide identification, description, units of measure, and the computational source for each ROLOSS SU input and output data element. Table 111 identifies terms that are used internal to the ROLOSS SU and whose value must be retained from SU call to SU call for reasons of computational efficiency.

Table 109. ROLOSS SU input data element requirements.

Name	Description	Units	Source
C_{lut}	Logical flag used to indicate if surface clutter calculations are desired.	N/A	Calling CSCI
Δx_{RO}	RO range interval	meters	ROCALC SU
Fd^2	Magnitude array, direct ray	N/A	ROCALC SU
Fr^2	Magnitude array, reflected ray	N/A	ROCALC SU
fsl	Free space loss array for output ranges	dB	APMINIT CSC
gas_{loss}	Gaseous absorption loss at range r_{out}	dB	APMSTEP CSC
$hlim$	Array containing the height at each output range separating the RO region from the PE (at close ranges) and XO (at far ranges) regions	meters	FILLHT SU
i_{ROn}	Array index for next range in RO region	N/A	ROCALC SU
i_{ROp}	Array index for previous range in RO region	N/A	ROCALC SU
i_{stp}	Current output range step index	N/A	Calling SU
j_{max}	Array index for maximum output height in RO region	N/A	Calling SU
j_{min}	Array index for minimum output height in RO region	N/A	Calling SU
k_{max}	Array index for maximum angle in RO region at range x_{ROn}	N/A	ROCALC SU
k_{minn}	Array index for minimum angle in RO region at range x_{ROn}	N/A	ROCALC SU
k_{minp}	Array index for minimum angle in RO region at range x_{ROp}	N/A	ROCALC SU
$lang$	Propagation angle and factor output flag '.true.'= Output propagation angle and propagation factor for direct and reflected ray (where applicable). '.false.' = Do not output propagation angles and factors	N/A	CALLING CSCI
Ω	Total phase angle array	radians	ROCALC SU

Table 109. ROLOSS SU input data element requirements. (continued)

Name	Description	Units	Source
lang	Propagation angle and factor output flag ‘.true.’= Output propagation angle and propagation factor for direct and reflected ray (where applicable). ‘.false.’ = Do not output propagation angles and factors	N/A	Calling CSCI
Ω	Total phase angle array	radians	ROCALC SU
$RO\alpha_{dir}$	Array of propagation angles for direct rays	radians	ROCALC SU
$RO\alpha_{ref}$	Array of propagation angles for reflected rays	radians	ROCALC SU
r_{out}	Current output range	meters	Calling SU
x_{ROp}	Previous range in RO region	meters	ROCALC SU
y_{fref}	Ground elevation height at source	meters	APMINIT CSC
z_c	Height at which to compute propagation factor for clutter calculations relative to hm_{ref}	meters	APMINIT CSC
zro	Array of output heights in RO region	meters	APMINIT CSC

Table 110. ROLOSS SU output data element requirements.

Name	Description	Units
mpfl	Propagation factor and loss array	cB
propaf	Two-dimensional array, containing the propagation angles and factors for the direct and reflected rays (where applicable) for all output height/range points	dB, radians

Table 111. ROLOSS SU save data element requirements.

Name	Description	Units	Source
$\Delta\alpha d_{hi}$	Difference in the direct ray angle along the RO step above the desired point	radians	ROLOSS SU
$\Delta\alpha d_{lo}$	Difference in the direct ray angle along the RO step below the desired point	radians	ROLOSS SU
$\Delta\alpha r_{hi}$	Difference in the reflected ray angle along the RO step above the desired point	radians	ROLOSS SU
$\Delta\alpha r_{lo}$	Difference in the reflected ray angle along the RO step below the desired point	radians	ROLOSS SU
$\Delta\Omega_{hi}$	Difference in total phase lag angle along Δx_{RO} above desired APM output point	radians	ROLOSS SU
$\Delta\Omega_{lo}$	Difference in total phase lag angle along Δx_{RO} below desired APM output point	radians	ROLOSS SU
ΔFd_{lo}^2	Difference in direct ray magnitude along Δx_{RO} below desired APM output point	N/A	ROLOSS SU

Table 111. ROLOSS SU save data element requirements. (continued)

Name	Description	Units	Source
ΔFd_{hi}^2	Difference in direct ray magnitude along Δx_{RO} above desired APM output point	N/A	ROLOSS SU
ΔFr_{lo}^2	Difference in reflected ray magnitude along Δx_{RO} below desired APM output point	N/A	ROLOSS SU
ΔFr_{hi}^2	Difference in reflected ray magnitude along Δx_{RO} above desired APM output point	N/A	ROLOSS SU

5.2.21 Save Profile (SAVEPRO) SU

The SAVEPRO SU stores the gradients and heights of the current refractivity profile, upon each reference to the FZLIM SU, from the top of the PE calculation region to the maximum user-specified height.

Upon entering, the current profile height array *htdum* is searched to find the index i such that $htdum_i$ is the first height in the profile that is greater than the maximum PE calculation height, z_{lim}. The counter l_{new} is then initialized to -1.

Next, the gradients are calculated and stored, along with corresponding heights, as follows

$$grad_{l_{new},iz} = \frac{refdum_{j+1} - refdum_j}{htdum_{j+1} - htdum_j},$$

$$htr_{l_{new},iz} = htdum_j \,,$$

where j is incremented by one from i to *lvlep*-1, l_{new} is incremented by one with each increment in j, and *iz* represents the range step index for XO calculations.

Before exiting, the last height level in *htdum* is stored and the final number of levels, l_{new}, in the iz^{th} profile (represented by *grad* and *htr*) is stored in array *lvl*.

Table 112 and Table 113 provide identification, description, units of measure, and the computational source for each SAVEPRO SU input and output data element.

Table 112. SAVEPRO SU input data element requirements.

Name	Description	Units	Source
htdum	Height array for current profile	meters	REFINTER SU
iz	Number of calculation range steps for XO region	N/A	FZLIM SU
lvlep	Number of height/refractivity levels in profile *refdum* and *htdum*	N/A	REFINTER SU
refdum	M-unit array for current profile	M-units	REFINTER SU
z_{lim}	Maximum height in PE calculation region	meters	FFTPAR SU

Table 113. SAVEPRO SU output data element requirements.

Name	Description	Units
grad	Two-dimensional array containing gradients of each profile used in XO calculations	M-units /meter
htr	Two-dimensional array containing heights of each profile used in XO calculations	meters
lvl	Number of height levels in each profile used in XO calculations	N/A

5.2.22 Spectral Estimation (SPECEST) SU

The SPECEST SU determines the outward propagation angle at the top of the PE calculation region, or the grazing angle at the lower part of the PE region, and the propagation angle for all desired output receiver points within the PE region based on spectral estimation. The outward propagation angle is used for XO calculations and the grazing angle is used for rough surface calculations. All other propagation angles are stored in *propaf* and returned to the calling CSCI.

Upon entering the SPECEST SU, if the outward propagation angle is to be determined (i_{flag} = 0), the topmost n_p points (within the unfiltered portion) of the complex PE field are separated into their real and imaginary components, *xp* and *yp*, respectively. If the grazing angle is to be determined (i_{flag} = 1), then the lowest n_p points of the complex PE field are used. A window filter is then applied to both real and imaginary component arrays by multiplying each element in *xp* and *yp* by each corresponding element in the filter array *filtp* for indices between ¾ n_p and n_p.

Next, the array elements in *xp* and *yp* are set to 0 for indices from n_p+1 to n_s-1. [Note that both *xp* and *yp* are arrays of size n_s.] The DRST SU is then referenced to obtain the spectral field components.

The spectral amplitudes in dB are then given by

$$spectr_i = 10\,\mathbf{LOG}_{10}\left[\mathbf{MAX}\left(10^{-10}, \sqrt{xp_i^2 + yp_i^2}\right)\right]; \quad \mathrm{i} = 0, 1, 2, \ldots, n_s - 1\,.$$

Next, a 3-point average is performed on *spectr* to determine the bin, or index i_{peak}, at which the peak spectral amplitude occurs. Once i_{peak} has been determined, the outward propagation angle is calculated as

$$\vartheta_{out} = \mathbf{SIN}^{-1}\left(\frac{\lambda\, i_{peak}}{2\, n_s \Delta z_{PE}}\right).$$

Table 114 and Table 115 provide identification, description, units of measure, and the computational source for each SPECEST SU input and output data element.

Table 114. SPECEST SU input data element requirements.

Name	Description	Units	Source
Δz_{PE}	PE mesh height increment (bin width in *z*-space)	meters	FFTPAR SU
filtp	Array filter for spectral estimation calculations	N/A	APMINIT CSC
i_{flag}	Flag indicating if spectral estimation is to be performed on lower PE field or upper PE field 0 = upper PE field 1 = lower PE field	N/A	Calling SU
jz_{lim}	PE bin # corresponding to z_{lim}, i.e., $z_{lim} = jz_{lim}\ \Delta z_{PE}$	N/A	APMINIT CSC
ln_p	Power of 2 transform size used in spectral estimation calculations; i.e., $n_p = 2^{ln_p}$	N/A	APMINIT CSC
np_{34}	¾ n_p	N/A	APMINIT CSC
n_p	Number of bins in upper PE region to consider for spectral estimation.	N/A	APMINIT CSC
n_s	Transform size for spectral estimation calculations	N/A	APMINIT CSC
U	Complex field at current PE range *r*	μV/m	PESTEP SU
xo_{con}	Constant used in determining ϑ_{out}	N/A	APMINIT CSC
y_{cur}	Height of ground at current range *r*	meters	PESTEP SU

Table 115. SPECEST output data element requirements.

Name	Description	Units
spectr	Spectral amplitude of field	dB
ϑ_{out}	Outward propagation angle at top of PE region	radians
xp	Real part of spectral portion of PE field	μV/m
yp	Imaginary part of spectral portion field	μV/m

5.2.23 Surface Impedance (SURFIMP) SU

The SURFIMP SU computes the complex normalized surface impedance for rough sea surface conditions, given the wind speed and the frequency. The SURFIMP SU implements a modified version Sailors (1997) of the original Barrick (1971a, 1971b) model for the normalized rough sea surface impedance for HF frequencies.

The SU begins by converting the internal wind speed input variable, *ws*, from meters/second to knots using the conversion:

$$ws(\text{knots}) = 1.94\ ws(\text{m/s}).$$

The SU then populates, from internal DATA statements, real polynomial coefficient arrays appropriate to the real (*cons1r, cons2r, cons3r, cons4r, cons5r*) and imaginary (*cons1i, cons2i, cons3i, cons4i, cons5i*) parts of the complex normalized surface impedance. The arrays appropriate for the real part of the normalized impedance are then passed, in five sequential function calls, along with the wind speed, to the FN_POLY5 SU for the determination of the five polynomial coefficients required for input to the FN_POLY4 SU. The polynomial coefficients returned from the sequential FN_POLY5 SU calls are stored in the *constr* array variable which is then passed to the FN_POLY4 SU, along with the frequency f_{MHz}, for determination of the real part of the complex normalized rough sea surface impedance, ξ_r.

This process is then repeated, passing the appropriate coefficient arrays (*cons1i, cons2i, cons3i, cons4i, cons5i*) along with the wind speed variable to the FN_POLY5 SU for determination of the polynomial coefficients for FN_POLY4. These coefficients are then passed to the FN_POLY4 SU, along with the frequency f_{MHz}, for determination of the imaginary part of the normalized rough sea surface impedance, ξ_i.

The output of the SURFIMP SU is the double precision complex normalized rough sea surface impedance given by

$$\xi = \xi_r + j\,\xi_i\,.$$

Table 116 and Table 117 provide identification, description, units of measure, and the computational source for each SURFIMP SU input and output data element.

Table 116. SURFIMP input data element requirements.

Name	Description	Units	Source
ws	Wind speed	meters/second	Calling SU
f_{MHz}	Frequency	MHz	Calling SU

Table 117. SURFIMP output data element requirements.

Name	Description	Units
ξ	Normalized rough sea surface impedance	N/A

5.2.24 Troposcatter (TROPOSCAT) SU

The TROPOSCAT SU calculates the loss due to troposcatter at and beyond the radio horizon for an array of receiver heights.

Upon entering the TROPOSCAT SU, the current output range r_{out} is updated, and the surface refractivity and associated variables are also initialized. The surface refractivity sn_{ref} is initialized according to

$$sn_{ref} = \frac{1}{2}\left(snref_{tx} + snref_0\right).$$

A term used in the troposcatter transmission loss calculation, sn_1, is determined from

$$sn_1 = 0.031 - 0.00232\, sn_{ref} + 5.67 \times 10^{-6}\, sn_{ref}^{\;2},$$

along with a loss term $tlst_s$ for smooth surface as

$$tlst_s = tlst_{wr} - .2sn_{ref}\ .$$

Next, the tangent angle from the source to the surface, ϑ_1, is initialized to its value for smooth surface, ϑ_{1s}. If performing a terrain case (f_{ter} = '.true.'), the index j_{t2} is initialized where the first occurance of the condition $j_{t2}\Delta r_{PE} > r_{out}$ is met. The index j_{t1} is set equal to the index location within $\vartheta 1t$, up to j_{t2}-1, where the minimum value occurs. The tangent angle from the source height ϑ_1 is then initialized to $\vartheta 1t_{j_{t1}}$ and the corresponding range d_1 is initialized $j_{t1}\Delta r_{PE}$.

For each output height index j from j_s to j_e, the following steps are performed:

1. If running a smooth surface case (f_{ter} = '.false.') and r_{out} is less than the minimum range rdt_j at which diffraction field solutions are applicable for the current height, then the index is iterated until the loop is exited. Otherwise, the SU program flow continues with step 2.

2. The function FN_GET_TLOSS is referenced to determine the troposcatter loss and returns the total loss for each height $zout_j$. The total loss is then stored in array *rloss*.

If receiver heights relative to the local ground are specified, then steps 1 to 2 above are also performed for all heights in *zout_rtg* from 1 to n_{zout_rtg} with appropriate initialization of angle and height variables before referencing FN_GET_TLOSS. The final loss values are then stored in array *rloss_rtg*.

Table 118 and Table 119 provide identification, description, units of measure, and the computational source for each TROPOSCAT SU input and output data element.

Table 118. TROPOSCAT SU input data element requirements.

Name	Description	Units	Source
adif	Height differences between ant_{ref} and all output receiver heights	meters	TROPOINIT SU
d2s	Array of tangent ranges for all output receiver heights over smooth surface	meters	TROPOINIT SU
Δr_{PE}	PE range step	meters	PEINIT SU
e_k	Effective earth's radius factor	N/A	GET_K SU
f_{ter}	Logical flag indicating if terrain profile has been specified: '.true.' = terrain profile specified '.false.' = terrain profile not specified	N/A	APMINIT CSC
h_{minter}	Minimum height of terrain profile	meters	TERINIT SU
i_{PE}	Number of PE range steps	N/A	PEINIT SU
i_{stp}	Current output range step index	N/A	Calling SU
j_e	Ending receiver height index at which to compute troposcatter loss	N/A	Calling SU
j_s	Starting receiver height index at which to compute troposcatter loss	N/A	Calling SU
j_{t2}	Index counter for *tyh* array indicating location of receiver range	N/A	TROPOINIT SU APMSTEP CSC

Table 118. TROPOSCAT SU input data element requirements. (continued)

Name	Description	Units	Source
rdt	Array of minimum ranges at which diffraction field solutions are applicable (for smooth surface) for all output receiver heights.	meters	TROPOINIT SU
rloss	Propagation loss array	dB	Calling SU
rloss_rtg	Propagation loss computed relative to the local ground height at heights specified by *zout_rtg*	dB	Calling SU
rngout	Array containing all desired output ranges	meters	APMINIT CSC
$snref_0$	Surface refractivity taken from the refractivity profile with respect to mean sea level	M-unit	REFINIT SU
$snref_{tx}$	Surface refractivity at transmitter	M-unit	REFINIT SU
$\vartheta 0$	Array of angles used to determine common volume scattering angle	radians	TROPOINIT SU
ϑ_{1s}	Tangent angle from source (for smooth surface)	radians	TROPOINIT SU
$\vartheta 2s$	Array of tangent angles from all output receiver heights - used with smooth surface	radians	TROPOINIT SU
$\vartheta 1t$	Array of tangent angles from source height - used with terrain profile	radians	TROPOINIT SU
$tlst_{wr}$	Troposcatter loss term	dB	TROPOINIT SU
twoka	Twice the effective earth radius	meters	GET_K SU
y_{ground}	Height of the surface at the current output range step	meters	Calling SU
zout	Array containing all desired output heights referenced to h_{minter}	meters	APMINIT CSC
zout_rtg	Receiver heights specified relative to the local ground height.	meters	Calling CSCI

Table 119. TROPOSCAT SU output data element requirements.

Name	Description	Units
rloss	Propagation loss array	dB
rloss_rtg	Propagation loss computed relative to the local ground height at heights specified by *zout_rtg*	dB

5.3 EXTENDED OPTICS INITIALIZATION (XOINIT) CSC

The XOINIT CSC initializes the range, height, and angle arrays in preparation for XO calculations and to reference the CLUTTER SU if clutter values are desired.

Upon entering the XOINIT CSC, if C_{lut} is '.true.' the CLUTTER SU is referenced to compute the clutter-to-noise ratio (*CNR*). Next, the value of i_{xostp} is tested. If i_{xostp} is equal to 0, then the APMCLEAN SU is referenced to deallocate all arrays used in the APM application and the CSC is exited. If i_{xostp} is greater than 0, then the following procedure is performed.

The arrays *curang* and *curng*, used for storage of traced local angles and ranges, respectively, are allocated and initialized to the range and angle values stored in *ffacz*. The array *curht* is allocated and initialized to the height of the top of the PE calculation region, z_{lim}. The array *igrd*, used for storage of starting refractivity gradient level [at which to begin ray tracing], is allocated and initialized to 0. The two-dimensional array *prfhxo*, containing final output heights and propagation factors, along with the dummy array *dum*, used for temporary storage, are also allocated and initialized to 0.

If f_{ter} is '.true.', then the MEANFILT SU is referenced twice to perform a 9-point smoothing operation on the angle values, using *dum* for temporary storage of angles after the first pass smoothing operation. Next, the starting height index at which to begin XO calculations, j_{xstart} is initialized to the ending height index for PE calculations, j_{end}, plus one. Finally, *dum* is deallocated before exiting.

Table 120 and Table 121 provide identification, description, units of measure, and the computational source for each XOINIT CSC input and output data element.

Table 120. XOINIT CSC input data element requirements.

Name	Description	Units	Source
C_{lut}	Logical flag used to indicate if surface clutter calculations are desired.	N/A	Calling CSCI
ffacz	Array containing propagation factor, range, and propagation angle at z_{lim}	dB, meters, radians	FZLIM SU
f_{ter}	Logical flag indicating if terrain profile has been specified: .true. = terrain profile specified .false. = terrain profile not specified	N/A	APMINIT CSC
i_{xostp}	Current output range step index for XO calculations	N/A	Calling SU
iz	Number of propagation factor, range, angle triplets stored in *ffacz*	N/A	FZLIM SU APMINIT CSC
iz_{max}	Maximum number of points allocated for arrays associated with XO calculations	N/A	APMINIT CSC
j_{end}	Ending index within *mpfl* of PE loss values	N/A	Calling SU
z_{lim}	Height limit for PE calculation region	meters	GETTHMAX SU

Table 121. XOINIT CSC output data element requirements.

Name	Description	Units
CNR	Array of clutter-to-noise ratio values	dB
curang	Array of current local angles for each ray being traced in XO region	radians
curht	Array of current local heights for each ray being traced in XO region	meters
curng	Array of current local ranges for each ray being traced in XO region	meters
i_{error}	Error flag	N/A
igrd	Integer indexes indicating at what refractive gradient level to begin ray tracing for next XO range step for each ray in XO region.	N/A
j_{xstart}	Starting index within *mpfl* of XO loss values	N/A
prfhxo	Two-dimensional array of propagation factor and heights for each ray traced in XO region to range r_{out}	dB,meters

5.3.1 APM Clean (APMCLEAN) SU

The APMCLEAN SU deallocates all dynamically dimensioned arrays used in one complete run of APM calculations.

Upon entry, all arrays that were dynamically allocated at the beginning of the current application are now deallocated.

Table 122 and Table 123 provide identification, description, units of measure, and the computational source for each APMCLEAN SU input and output data element.

Table 122. APMCLEAN SU input data element requirements.

Name	Description	Units	Source
adif	Height array used for troposcatter calculations	meters	TROPOINIT SU
curang	Array of current local angles for each ray being traced in XO region	radians	EXTO SU XOINIT CSC
curht	Array of current local heights for each ray being traced in XO region	meters	EXTO SU XOINIT CSC
curng	Array of current local ranges for each ray being traced in XO region	meters	EXTO SU XOINIT CSC
d2s	Array of tangent ranges for all output receiver heights over smooth surface	meters	TROPOINIT SU
dielec	Two-dimensional array containing the relative permittivity and conductivity; $dielec_{1,i}$ and $dielec_{2,i}$, respectively.	N/A, S/m	Calling CSCI, DIEINIT SU
envpr	Complex [refractivity] phase term array interpolated every Δz_{PE} in height	N/A	PEINIT SU PESTEP SU

Table 122. APMCLEAN SU input data element requirements. (continued)

Name	Description	Units	Source
ffacz	Array containing propagation factor, range, and propagation angle at z_{lim}	dB, meters, radians	FZLIM SU
ffat1m	Propagation factor array computed at 1 m above the surface.	dB	CALCLOS SU, FEDR SU, FEM SU, ROLOSS SU
ffrout	Array of propagation factors at each output range beyond r_{atz} and at height z_{lim}	dB	CALCLOS SU
filt	Cosine-tapered (Tukey) filter array	N/A	PEINIT SU
filtp	Array filter for spectral estimation calculations	N/A	APMINIT CSC
frsp	Complex free space propagator term array	N/A	PEINIT SU
fsl	Free space loss array for output ranges	dB	APMINIT CSC
γc	Dynamically allocated array of constants describing the backscattering effectiveness of the surface	dB	Calling CSCI
γrng	Dynamically allocated array of ranges corresponding to the values in γc	meters	Calling CSCI
gr	Intermediate M-unit gradient array, RO region	(M-unit/m)10^{-6}	REFINIT SU
grad	Two-dimensional array containing gradients of each profile used in XO calculations	M-units /meter	SAVEPRO SU
grdum	Array of refractivity gradients defined by profile *htdum* and *refdum*	M-units /meter	REFINIT SU REFINTER SU
hfangr	Array of user-defined cut-back angles. This is used only for user-defined height-finder antenna type.	radians	APMINIT CSC
hlim	Array containing height at each output range separating the RO region from the PE (at close ranges) and XO (at far ranges) regions	meters	GETTHMAX SU
href	Heights of refractivity profile with respect to y_{ref}	meters	PROFINT SU
ht	PE mesh height array of size n_{fft}	meters	PEINIT SU
htdum	Height array for current interpolated profile	meters	REFINIT SU REFINTER SU
htfe	Array containing the height at each output range separating the FE region from the RO region (full hybrid mode), or the FE region from the PE region (partial hybrid mode)	meters	FILLHT SU
htr	Two-dimensional array containing heights of each profile used in XO calculations	meters	SAVEPRO SU
igrd	Integer indexes indicating at what refractive gradient level to begin ray tracing for next XO range step for each ray in XO region.	N/A	XOINIT CSC

Table 122. APMCLEAN SU input data element requirements. (continued)

Name	Description	Units	Source
igrnd	Integer array containing ground type composition for given terrain profile - can vary with range. Different ground types are: 0 = seawater 1 = freshwater 2 = wet ground 3 = medium dry ground 4 = very dry ground 5 = ice at -1 degree C 6 = ice at -10 degree C 7 = user-defined (in which case, values of relative permittivity and conductivity must be given).	N/A	Calling CSCI
lvl	Number of height levels in each profile used in XO calculations	N/A	SAVEPRO SU
nc^2	Array of complex dielectric constants	N/A	DIEINIT SU
prfhxo	Array of propagation factor and heights for each ray traced in XO region to range r_{out}	dB,meters	XOINIT CSC
profint	Profile interpolated to every Δz_{PE} in height	M-units	REFINTER SU
Ψ	Array of interpolated grazing angles at each PE range step	radians	GRAZE_INT SU
q	Intermediate M-unit difference array, RO region	2M-unit 10^{-6}	REFINIT SU
rdt	Array of minimum ranges at which diffraction field solutions are applicable (for smooth surface) for all output receiver heights.	meters	TROPOINIT SU
refdum	M-unit array for current interpolated profile	M-units	REFINIT SU REFINTER SU
refref	Refractivity profile with respect to y_{ref}	M-units	PROFINT SU
rfac1	Propagation factor at valid output height points from PE field at range r_{last}	dB	CALCLOS SU
rfac2	Propagation factor at valid output height points from PE field at range r	dB	CALCLOS SU
rgrnd	Array containing ranges at which varying ground types apply.	meters	Calling CSCI
rlogo	Array containing 20 times the logarithm of all output ranges	N/A	APMINIT CSC
rloss	Propagation loss	dB	ALLARRAY_APM CALCLOS SU EXTO SU TROPOSCAT SU
rloss_rt g	Propagation loss computed relative to the local ground height at heights specified by *zout_rtg*	dB	ALLARRAY_APM CALCLOS SU TROPOSCAT SU
rm	Intermediate M-unit array, RO region	M-unit 10^{-6}	REFINIT SU
rngout	Array containing all desired output ranges	meters	APMINIT CSC

Table 122. APMCLEAN SU input data element requirements. (continued)

Name	Description	Units	Source
rn	Array of R_T to the i^{th} power (e.g., $rn_i = R_T^i$)	N/A	GETALN SU
rsqrd	Array containing the square of all desired output ranges	meters^2	APMINIT CSC
spectr	Spectral amplitude of field	dB	SPECEST SU
$\vartheta 0$	Array of angles used to determine common volume scattering angle	radians	TROPOINIT SU
$\vartheta 2s$	Array of tangent angles from all output receiver heights - used with smooth surface	radians	TROPOINIT SU
$\vartheta 1t$	Array of tangent angles from source height - used with terrain profile	radians	TROPOINIT SU
Θ_{rout}	Two-dimensional array containing the propagation angle spectrally estimated from PE at n_{ang} height points and at every output range step r_{out}	radians	RET_GRAZE SU
tang	Tangent of angle array from terrain slopes.	radians	PEINIT SU
tyh	Adjusted height points of terrain profile	meters	PEINIT SU
U	Complex PE field	μV/m	PESTEP SU
udum	Real or imaginary part of complex field array	μV/m	FFT SU
Ulast	Complex PE field at range r_{last}	μV/m	PESTEP SU
w	Difference equation of complex PE field	μV/m^2	PESTEP SU
xp	Real part of spectral portion of PE field	μV/m	SPECEST SU
ym	Particular solution of difference equation	μV/m	PESTEP SU
yp	Imaginary part of spectral portion field	μV/m	SPECEST SU
zout	Array containing all desired output heights referenced to h_{minter}	meters	APMINIT CSC
zoutma	Output height point relative to “real” ant_{ref}	meters	APMINIT CSC
zoutpa	Output height point relative to “image” ant_{ref}	meters	APMINIT CSC
zRO	Array of output heights in RO region	meters	APMINIT CSC
zrt	Intermediate height array, RO region	meters	REFINIT SU
zxo	Height of the ground at the current output range step	meters	CALCLOS SU

Table 123. APMCLEAN CSC output data element requirements.

Name	Description	Units
i_{error}	Error flag indicator: non-zero if error has occurred in deallocation procedure	N/A

5.3.2 Clutter-to-Noise (CLUTTER) SU

The CLUTTER SU calculates the returned CNR at each range r_{out} based on the radar range equation.

The reflectivity computed for that portion of the path over water is based on a modification to the Georgia Institute of Technology (GIT) model. However, the GIT model is valid for frequencies above 1 GHz. Therefore, for paths over water and for frequencies less than 1 GHz, the reflectivity is determined using the same model as that over land, detailed below.

Upon entering the SU the noise power, P_N, and a constant, *Con*, based on system parameters and used in the radar equation, are determined according to

$$Con = 10\,LOG_{10}\left(\frac{\lambda^2 P_t 10^3}{(4\pi)^3}\right) + 2\,G - L_{sys},$$

$$P_N = 10\,LOG_{10}\left(\frac{4\times 10^{-15}}{\tau}\right) + N_f,$$

where τ is the system pulse length in microseconds, P_t is the transmitter peak power in kW, G is the transmitting antenna gain (transmitting and receiving antenna are assumed to be equal), L_{sys}, is the assumed system loss, and N_f is the noise figure in dB.

Other constants used in determining the area of the clutter cell are computed for subsequent use in the GIT model and for clutter cross section model used over land:

$$Ac_{GIT} = \frac{\theta_{hbw} c_o \tau}{2\sqrt{2}},$$

$$Acx_{low} = c_o \tau\, TAN\left(\theta_{hbw}/2\right),$$

$$Acx_{high} = \pi\, TAN\left(\mu_{bwr}/2\right) TAN\left(\theta_{hbw}/2\right).$$

Next, if any of the path is over water and the frequency is greater than 1 GHz, then the GIT flag, l_{GIT}, is set to '.true.' and the GIT_INIT SU (if only one wind speed has been specified) and the SPMINIT SU are referenced to initialize all necessary variables used in computing the clutter over water.

Next, steps 1 through 9 are performed for each index *i* ranging from 1 to n_{rout}.

1. The grazing angle, ψ_{rout}, and range, r$_{out}$ are initialized:

$$\psi_{rout} = grz\_rout_i$$
$$r_{out} = rngout_i$$

If the current range corresponds to that part of the path over land or the frequency is less than 1 GHz (l_{GIT} = '.false.'), then the SU continues with steps 2 through 3; otherwise, the SU proceeds with steps 4 through 8.

2. The area of the clutter cell, A_c, is determined based on high and low grazing angle formulas:

$$Ac_{low} = \frac{Acx_{low} r_{out}}{COS(\psi_{rout})},$$
$$Ac_{high} = \frac{Acx_{high} r_{out}^2}{SIN(\psi_{rout})},$$
$$A_c = 10LOG_{10}\left(MIN\left(Ac_{low}, Ac_{high}\right)\right).$$

3. The reflectivity, or clutter cross section per unit area, $\sigma°$, over land is then determined from

$$\sigma^o = \gamma c_{igrc} + 10\,LOG_{10}\left[SIN(\psi_{rout})\right],$$

where *igrc* is the index counter for the γc array at the current range. The SU then proceeds to step 9.

4. If the current range corresponds to that portion of the path over water, then the GIT_INIT SU is referenced if more than one wind speed has been specified. The range at which the current grazing angle occurs for a standard atmosphere is then determined from

$$r_{spm} = \sqrt{a_{ekst}^2\,\psi_{rout}^2 + 2a_{ekst}ant_{ref}} - a_{ekst}\psi_{rout}\,.$$

5. The propagation factor (in dB) for a standard atmosphere at this range, F_{spm}, is then obtained from referencing the SPM SU.

6. Next, several variables are computed for use in computing the reflectivity:

$$\sigma_{\varphi} = \sigma_{term}\,\psi_{rout}\,,$$
$$a_i = \frac{\sigma_{\varphi}^4}{\left(1+\sigma_{\varphi}^4\right)},$$
$$a_u = e^{au_{term}\left(1-2.8\psi_{rout}\right)}\,,$$

where σ_{term} and au_{term} are determined in the GIT_INIT SU.

7. The GIT reflectivity, σ_{GIT}^o, is then computed as

$$\left.\begin{array}{l}\sigma_H^o = 10\,LOG_{10}\left(3.9\times10^{-6}\lambda\psi_{rout}^{0.4}a_i a_u a_w\right),\\ \sigma_V^o = \sigma_H^o + \sigma_{VH2} + 1.27LN\left(\psi_{rout} + 10^{-4}\right)\end{array}\right. \text{ for } 3000 \le f_{MHz} < 10{,}000 \text{ MHz;}$$

$$\left.\begin{array}{l}\sigma_H^o = as\,above\,,\\ \sigma_V^o = \sigma_H^o + \sigma_{VH1} + 2.46LN\left(\psi_{rout} + 10^{-4}\right)\end{array}\right. \text{ for } f_{MHz} < 3000 \text{ MHz;}$$

$$\left.\begin{array}{l}\sigma_H^o = 10\,LOG_{10}\left(5.78\times10^{-6}\psi_{rout}^{0.547}a_i a_u a_w\right),\\ \sigma_V^o = \sigma_H^o + \sigma_{VH3} + 1.31LN\left(\psi_{rout}\right)\end{array}\right. \text{ for } f_{MHz} \ge 10{,}000 \text{ MHz,}$$

$$\sigma_{GIT}^o = \sigma_H^o\,,\ \ for\ \ H\ \ pol,$$
$$\sigma_{GIT}^o = \sigma_V^o\,,\ \ for\ \ V\ \ pol,$$

where the terms a_w and $\sigma_{VH1\text{-}3}$ are determined in the GIT_INIT SU.

8. The reflectivity and the area of the clutter cell for over water paths are then computed according to

$$\sigma^o = \sigma_{GIT}^o - 2F_{spm}\,,$$
$$A_c = 10\,LOG_{10}\left(r_{out}Ac_{GIT}\right).$$

9. The return clutter power at the current range r_{out} is then computed:

$$C = Con + \sigma^o + 2\,ffat1m_i + A_c - 40LOG_{10}\left(r_{out}\right).$$

Once the clutter power has been computed for all ranges and stored in an array, the clutter-to-noise ratio is determined for all ranges by subtracting the noise power:

$$CNR_i = C_i - P_N \text{, for } i = 1, 2, 3, \ldots n_{rout}.$$

Table 124 and Table 125 provide identification, description, units of measure, and the computational source for each CLUTTER SU input and output data element.

Table 124. CLUTTER SU input data element requirements.

Name	Description	Units	Source
a_{ekst}	4/3 effective earth's radius	meters	APM_MOD
ant_{ref}	Transmitting antenna height relative to h_{minter}	meters	APMINIT CSC
f_{MHz}	Frequency in MHz	MHz	Calling CSCI
$ffat1m$	Propagation factor array computed at 1 m above the surface.	dB	CALCLOS SU, FEDR SU, FEM SU, ROLOSS SU
f_{ter}	Logical flag indicating if terrain profile has been specified: .true. = terrain profile specified .false. = terrain profile not specified	N/A	APMINIT CSC
G	Gain of transmit/receive antennas	dBi	Calling CSCI
γc	Dynamically allocated array of constants describing the backscattering effectiveness of the surface	dB	Calling CSCI
γrng	Dynamically allocated array of ranges corresponding to the values in γc	meters	Calling CSCI
Ψ_{rout}	Array of grazing angles at each output range r_{out}	radians	RET_GRAZE SU
i_{gc}	Number of γc values for a particular application of APM	N/A	Calling CSCI
i_o	Starting index for $mpfl$ array: 0 = 1st calculated output point is at surface 1 = 1st calculated output point is at height Δz_{out}	N/A	APMINIT CSC
i_{PE}	Number of PE range steps	N/A	PEINIT SU
i_{pol}	Polarization flag: 0 = horizontal polarization 1 = vertical polarization	N/A	Calling CSCI
λ	Wavelength	meters	APMINIT CSC
L_{sys}	Miscellaneous system losses	dB	Calling CSCI
μ_{bwr}	Antenna vertical beamwidth	radians	APMINIT CSC
N_f	Noise figure	dB	Calling CSCI
n_{rout}	Integer number of output range points desired	N/A	Calling CSCI
n_w	Number of wind speeds	N/A	Calling CSCI
P_t	Transmitter peak power	kW	Calling CSCI

Table 124. CLUTTER SU input data element requirements. (continued)

Name	Description	Units	Source
$rlogo$	Array containing 20 times the logarithm of all output ranges	dB	APMINIT CSC
$rngout$	Array containing all desired output ranges	meters	APMINIT CSC
ruf	Logical flag indicating if rough sea surface calculations are required ‘.true.’ = perform rough sea surface calculations ‘.false.’ = do not perform rough sea surface calculations	N/A	APMINIT CSC
θ_{hbw}	Antenna horizontal beam width	radians	APMINIT CSC
τ	Pulse length/width	μsec	Calling CSCI
y_{fref}	Ground elevation height at source	meters	APMINIT CSC
z_c	Height at which to compute propagation factor for clutter calculations relative to hm_{ref}	meters	APMINIT CSC

Table 125. CLUTTER SU output data element requirements.

Name	Description	Units
CNR	Clutter-to-noise ratio array	dB

5.3.3 Diffraction Loss (FN_DLOSS) Function

The FN_DLOSS function computes the diffraction region loss based on the CCIR model. Please refer to Hitney et al. (1984) for a complete description.

5.3.4 Get Theta (GETTHETA) SU

The GETTHETA SU computes the optical phase-lag difference angle based on the reflection range. Please refer to Hitney et al (1984). for a complete description.

5.3.5 GIT Initialization (GIT_INIT) SU

The GIT_INIT SU initializes all variables used in the calculation of the reflectivity based on the GIT model.

Upon entering the SU, the wind speed, ω_s, at the current range is determined by referencing the FN_CURWIND function. Next, the average wave height, h_{avg}, and wind direction are initialized according to

$$h_{avg} = \left(\frac{\omega_s}{8.67}\right)^{2.5},$$

$$\omega_d = wind_{dir}\left(\pi/180\right).$$

The following terms used in determining the upwind/downwind factor, a_u, and wind speed factor, a_w, are then computed:

$$\left.\begin{aligned} q_w &= 1.1(\lambda + 0.015)^{-0.4}, \\ au_{term} &= 0.2\,\mathrm{COS}(\omega_d)(\lambda + 0.015)^{-0.4} \end{aligned}\right\} \text{ for } f_{MHz} < 10000;$$

$$\left.\begin{aligned} q_w &= 1.93\,\lambda^{-0.04}, \\ au_{term} &= 0.25\,\mathrm{COS}(\omega_d)\,\lambda^{-0.33} \end{aligned}\right\} \text{ for } f_{MHz} \geq 10000.$$

Finally, the wind speed factor and several variables used in computing the reflectivity are determined:

$$a_w = \left(\frac{1.94\,\omega_s}{\left[1 + \omega_s / 15.4\right]} \right)^{q_w},$$

$$\sigma_{term} = \frac{(14.4\lambda + 5.5)h_{avg}}{\lambda},$$

$$\sigma_{VH1} = 22.2 + 3.76\,\mathrm{LN}(\lambda) - 1.73\,\mathrm{LN}(h_{avg} + 0.015),$$

$$\sigma_{VH2} = 9.7 + 1.09\,\mathrm{LN}(\lambda) - 1.05\,\mathrm{LN}(h_{avg} + 0.015),$$

$$\sigma_{VH3} = 18.55 + 3.43\,\mathrm{LN}(\lambda) - 1.38\,\mathrm{LN}(h_{avg}).$$

Table 126 and Table 127 provide identification, description, units of measure, and the computational source for each GIT_INIT SU input and output data element.

Table 126. GIT_INIT SU input data element requirements.

Name	Description	Units	Source
f_{MHz}	Frequency in MHz	MHz	Calling CSCI
λ	Wavelength	meters	APMINIT CSC
n_w	Number of wind speeds	N/A	Calling CSCI
rngwind	Ranges of wind speeds entered: $rngwind_i$ = range of i^{th} wind speed	meters	Calling CSCI
rout	Current output range	meters	Calling SU
wind	Array of wind speeds	m/s	Calling CSCI
winddir	Angle between antenna boresight and upwind direction	degrees	Calling CSCI

Table 127. GIT_INIT SU output data element requirements.

Name	Description	Units
au_{term}	Term in computing the upwind/downwind factor	N/A
a_w	Wind speed factor	N/A
σ_{term}	Term used in computing the GIT reflectivity	N/A
$\sigma_{VH1\text{-}3}$	Terms used in computing the GIT reflectivity	N/A

5.3.6 GofZ (GOFZ) Function

The GOFZ function computes the diffraction region height-gain in decibels, based on the CCIR diffraction model. Please refer to Hitney et al.(1984) for a complete description.

5.3.7 Mean Filter (MEANFILT) SU

The MEANFILT SU performs a i_{sz}-point average smoothing operation on the array passed to it.

The array *arbef* is passed to the SU, along with the number of points over which to perform the smoothing operation, i_{sz}. Once the smoothing operation has been performed, the resulting "smoothed" points are stored in *araft* and passed back to the calling routine. The operation is performed as follows:

$$araft_k = \frac{1}{i_{sz}} \sum_{i=k-m'}^{k+m'} arbef_i \quad for\; k = m'+1, m'+2, \; ..., m-m',$$

where m' is ½(i_{sz} -1) and m is the size of the array *arbef*.

Table 128 and Table 129 provide identification, description, units of measure, and the computational source for each MEANFILT SU input and output data element.

Table 128. MEANFILT SU input data element requirements.

Name	Description	Units	Source
arbef	Array of angles before smoothing operation	radians	Calling SU
i_{sz}	Number of points over which to perform average smoothing	N/A	Calling SU
m	Size of array *arbef*	N/A	Calling SU

Table 129. MEANFILT SU output data element requirements.

Name	Description	Units
araft	Array of angles after smoothing operation	radians

5.3.8 Optical Region Limit (OPLIMIT) SU

The OPLIMIT SU calculates the maximum range in the optical region and the corresponding loss at that range. Please refer to Hitney et al. (1984) for a complete description.

5.3.9 Optical Difference (OPTICF) SU

The OPTICF SU calculate the optical path-length difference angle by solving a cubic equation for the reflection point range. Please refer to Hitney et al. (1984) for a complete description.

5.3.10 R1 Iteration (R1ITER) SU

The R1ITER SU finds the range of the reflection point corresponding to a particular launch angle. Please refer to Hitney et al. (1984) for a complete description.

5.3.11 Standard Propagation Model Initialization (SPM_INIT) SU

The SPM_INIT SU initializes many of the variables used throughout the SPM SU. Please refer to Hitney et al. (1984) for a complete description.

5.3.12 Standard Propagation Model (SPM) SU

The SPM SU computes the propagation factor for a standard atmosphere only, with the assumption of omnidirectional antenna patterns. Please refer to Hitney et al. (1984) for a complete description.

5.4 EXTENDED OPTICS STEP (XOSTEP) CSC

The XOSTEP CSC calculates the propagation loss in the XO region for one output range step.

Upon entering the XOSTEP CSC, the current execution mode is checked to determine if XO calculations will be necessary ($i_{hybrid} \neq 0$). If i_{hybrid} is 0, then the CSC is exited.

If i_{hybrid} is not equal to 0, the output range r_{out}, and the gaseous absorption loss gas_{loss} are updated. The *mpfl* values are initialized to -32767 from the index of the start of XO calculations, j_{xstart}, to the maximum number of height output points, n_{zout}. The EXTO SU is then referenced to calculate propagation factor and loss values in the XO region. Propagation factor and loss values are returned in *mpfl* from index j_{xstart} to j_{xe}.

If FE and RO calculations need to be performed ($i_{hybrid} = 1$), then the indices j_{fs} and j_{fe}, indicating the height index at which to start and end FE calculations, respectively, are determined. The FEM SU is then referenced to compute propagation factor and loss values for heights $zout_{j_{fs}}$ to $zout_{j_{fe}}$. Similarly for RO calculations, the indices j_{rs} and j_{re} are

determined, and the ROLOSS SU is referenced to compute propagation factor and loss values for heights $zout_{j_{rs}}$ to $zout_{j_{re}}$.

Finally, the index j_{xend} is set equal to the maximum of j_{xe}, j_{fe}, and j_{re}. If the last range value has been reached ($i_{stp} = n_{rout}$), then the APMCLEAN SU is referenced to deallocate all arrays allocated for the APM application.

Table 130 and Table 131 provide identification, description, units of measure, and the computational source for each XOSTEP CSC input and output data element.

Table 130. XOSTEP CSC input data element requirements.

Name	Description	Units	Source
gas_{att}	Gaseous absorption attenuation rate	dB/km	GASABS SU
$htfe$	Array containing the height at each output range separating the FE region from the RO region (full hybrid mode), or the FE region from the PE region (partial hybrid mode)	meters	FILLHT SU
ht_{lim}	Maximum height relative to h_{minter}	meters	TERINIT SU
i_{hybrid}	Integer indicating which sub-models will be used: 0 = pure PE model 1 = full hybrid model (PE + FE + RO + XO) 2 = partial hybrid model (PE + XO)	N/A	APMINIT CSC
i_{stp}	Current output range step index	N/A	Calling CSCI
j_{xstart}	Index at which valid propagation factor and loss values in *mpfl* start	N/A	Calling CSCI
n_{zout}	Integer number of output height points desired	N/A	Calling CSCI
$rngout$	Array containing all desired output ranges	meters	APMINIT CSC
$zout$	Array containing all desired output heights referenced to h_{minter}	meters	APMINIT CSC

Table 131. XOSTEP CSC output data element requirements.

Name	Description	Units
gas_{loss}	Loss due to gaseous absorption	dB
j_{xend}	Index at which valid propagation factor and loss values in *mpfl* end	N/A
$mpfl$	Propagation factor and loss array	cB
r_{out}	Current desired output range	meters

5.4.1 Extended Optics (EXTO) SU

The EXTO SU calculates propagation factor and loss based on XO techniques. The SU performs a ray trace on all rays within one output range step and returns the propagation factor and loss up to the necessary height; storing all angle, height, and range information for subsequent ray tracing upon the next reference to the SU.

Upon entering the SU, internal one-line ray trace functions are defined as

$$\mathrm{RADA1}(a,b)=a^2+2g_{rd}b,$$
$$\mathrm{RP}(a,b)=a+\frac{b}{g_{rd}},$$
$$\mathbf{AP}(a,b)=a+bg_{rd},$$
$$\mathbf{HP}(a,b,c)=a+\frac{b^2-c^2}{2g_{rd}}.$$

Next, the starting and ending index counters iz_s, iz_e, respectively, for the local angle, range, and height arrays; and the refractivity profile starting index i_{rps} are initialized to 1 for the first reference to the EXTO SU. The index iz_e is then determined such that $curng_{iz_e} \le r_{out} < curng_{iz_e+1}$. The integer counter k, indicating the number of propagation factor and heights in array *prfhxo*, is initialized to 0.

Ray trace steps 1 through 3 are performed for each ray; i.e., for each j^{th} angle, range, and height triplet, for j ranging from iz_s to iz_e.

1. At the start of the ray trace, the current local angle (a_0), range (r_0), height (h_0), and refractive gradient index (i_{grad}) are initialized to $curang_j$, $curng_j$, $curht_j$, and $igrd_j$, respectively. Next, refractive profile index, i_{rp}, is initialized to the maximum of j or i_{rps}. Finally, the refractivity gradient, g_{rd} is set equal to the gradient at the i_{grad}^{th} level of the i_{rp}^{th} profile, $grad_{i_{grad},i_{rp}}$. Ray trace steps 1.a through 1.d are then performed until the current local range r_0 becomes greater than or equal to r_{out}.

   a. The ending range, r_1, in the ray trace segment is set equal to the minimum of $ffacz_{i_{rp}+1,2}$ or r_{out}. If i_{rp} is equal to the number of stored triplets, iz, then r_1 is set equal to r_{out}.

   b. The j^{th} ray is then traced to r_1 and the resulting angle and height at the end of the segment is determined via the in-line functions as

$$a_1 = \mathrm{AP}(a_0, r_1 - r_0),$$
$$h_1 = \mathrm{HP}(h_0, a_1, a_0).$$

c. The ending height h_1 is then compared to the next height level in the current refractivity profile, $htr_{i_{grad}+1,i_{rp}}$, and if h_1 is greater than this height level, it is set equal to $htr_{i_{grad}+1,i_{rp}}$ and a new a_1 and r_1 are computed from

$$
\begin{aligned}
a_1 &= \sqrt{\mathrm{RADA1}(a_0, h_1 - h_0)} \\
r_1 &= \mathrm{RP}(r_0, a_1 - a_0)
\end{aligned}
.
$$

i_{grad} is then set to the minimum of i_{grad}+1 or $lvl_{i_{rp}}$-1.

d. The starting angle, range, and height for the next ray trace segment is updated, and if necessary, the refractivity profile index i_{rp} is updated to the minimum of i_{rp}+1 or iz_e. Steps 1.a through 1.d are then repeated for the next ray segment.

2. Once the ray has been traced to a range of r_{out} or greater, the current angle, range, and height arrays, *curang*, *curng*, and *curht*, respectively, are updated to the values for a_0, r_0, and h_0 for subsequent references to the EXTO SU.

3. The counter k for the propagation factor and height array is incremented by one and the array is updated according to

$$
\begin{aligned}
prfhxo_{k,1} &= ffacz_{j,1}\,, \\
prfhxo_{k,2} &= h_0\,.
\end{aligned}
$$

Once all rays have been traced, the starting profile index i_{rps} is updated to iz_e for the next reference to the EXTO SU, and the counter k is again incremented by one and the last values of *prfhxo* updated as follows,

$$
\begin{aligned}
prfhxo_{k,1} &= ffrout_{i_{stp},1}\,, \\
prfhxo_{k,2} &= ffrout_{i_{stp},2}\,.
\end{aligned}
$$

The number of traced XO height points, n_{xo}, at the current output range is then set to k. Note that at this point, all output heights in $prfhxo_{0:n_{xo},2}$ are decreasing from $prfhxo_{1,2}$ to $prfhxo_{n_{xo},2}$ and all traced heights in *curht* are decreasing from $curht_{iz_s}$ to $curht_{iz_e}$.

The starting index iz_s is then adjusted [for the next reference to the EXTO SU] if the topmost traced height $curht_{iz_s}$ is greater than ht_{lim}. If performing a terrain case, the output height points may not be continually decreasing from $prfhxo_{1,2}$ to $prfhxo_{n_{xo},2}$. In this case, *prfhxo* is sorted such that all height values are steadily decreasing. The ending index, j_{xe}, at which XO propagation factor and loss values will be calculated and stored

in *mpfl*, is set equal to n_{zout} and adjusted, if necessary, such that $zout_{j_{xe}}$ is less than $prfhxo_{1,2}$. Now, the counter index *ix* is initialized to n_{xo}. Next, the propagation factor is determined via linear interpolation on the values in *prfhxo*. Steps 1 through 2 are performed for each output height point $zout_j$ for *j* varying from j_{xs} to j_{xe}.

1. The counter *ix* is adjusted (if necessary) such that $prfhxo_{ix,2} \le zout_j < prfhxo_{ix\text{-}1,2}$.

2. The propagation factor (F_{dB}), propagation loss (*rloss*), and propagation angle ($propaf_{1,j}$) at height $zout_j$ are then calculated according to

$$
\begin{aligned}
frac &= \frac{zout_j - prfhxo_{ix,2}}{prfhxo_{ix-1,2} - prfhxo_{ix,2}}, \\
F_{dB} &= \text{FN\_PLINT}\left(prfhxo_{ix,1}, prfhxo_{ix-1,1}, frac\right), \\
rloss_j &= fsl_{i_{stp}} - F_{dB}, \\
propaf_{1,j} &= \text{FN\_PLINT}\left(prfhxo_{ix,3}, prfhxo_{ix-1,3}, frac\right).
\end{aligned}
$$

Once all propagation loss values have been computed, the TROPOSCAT SU is referenced to compute troposcatter loss, if necessary. Finally, the loss due to gasesous absorption is added to *rloss* and then converted to centibels and stored in *mpfl* before exiting.

Table 132 and Table 133 provide identification, description, units of measure, and the computational source for each EXTO SU input and output data element. Table 134 identifies terms that are used internal to the EXTO SU and whose value must be retained from SU call to SU call for reasons of computational efficiency.

Table 132. EXTO SU input data element requirements.

Name	Description	Units	Source
curang	Array of current local angles for each ray being traced in XO region	radians	EXTO SU XOINIT CSC
curht	Array of current local heights for each ray being traced in XO region	meters	EXTO SU XOINIT CSC
curng	Array of current local ranges for each ray being traced in XO region	meters	EXTO SU XOINIT CSC
ffacz	Array containing propagation factor, range, and propagation angle at z_{lim}	dB, meters, radians	FZLIM SU
ffrout	Array of propagation factors at each output range beyond r_{atz} and at height z_{lim}	dB	CALCLOS SU
fsl	Free space loss array for output ranges	dB	APMINIT CSC
f_{ter}	Logical flag indicating if terrain profile has been specified: .true. = terrain profile specified .false. = terrain profile not specified	N/A	APMINIT CSC
gas_{loss}	Gaseous absorption loss at range r_{out}	dB	APMSTEP CSC
grad	Two-dimensional array containing gradients of each profile used in XO calculations	M-units /meter	SAVEPRO SU
hlim	Array containing height at each output range separating the RO region from the PE (at close ranges) and XO (at far ranges) regions	meters	GETTHMAX SU
ht_{lim}	Maximum height relative to h_{minter}	meters	TERINIT SU
htr	Two-dimensional array containing heights of each profile used in XO calculations	meters	SAVEPRO SU
igrd	Integer indexes indicating at what refractive gradient level to begin ray tracing for next XO range step for each ray in XO region.	N/A	XOINIT CSC
i_{ratz}	Index of output range step in which to begin storing propagation factor and outgoing angle for XO region	N/A	APMINIT CSC
i_{stp}	Current output range step index	N/A	Calling SU
T_{ropo}	Troposcatter calculation flag: '.false.'= no troposcatter calcs '.true.' = troposcatter calcs	N/A	Calling CSCI
iz	Number of propagation factor, range, angle triplets stored in *ffacz*	N/A	FZLIM SU
j_{xs}	Index at which valid loss values in *mpfl* start	N/A	Calling SU
lvl	Number of height levels in each profile used in XO calculations	N/A	SAVEPRO SU
n_{zout}	Integer number of output height points desired	N/A	Calling CSCI
r_{out}	Current output range	meters	Calling SU
zout	Array containing all desired output heights referenced to h_{minter}	meters	APMINIT CSC
zxo	Height of the ground at the current output range step	meters	CALCLOS SU

Table 133. EXTO SU output data element requirements.

Name	Description	Units
curang	Array of current local angles for each ray being traced in XO region	radians
curht	Array of current local heights for each ray being traced in XO region	meters
curng	Array of current local ranges for each ray being traced in XO region	meters
hlim	Array containing height at each output range separating the RO region from the PE (at close ranges) and XO (at far ranges) regions	meters
igrd	Integer indexes indicating at what refractive gradient level to begin ray tracing for next XO range step for each ray in XO region	N/A
j_{xe}	Index at which valid loss values in *mpfl* end	N/A
mpfl	Two-dimensional propagation factor and loss array	cB
prfhxo	Two-dimensional array of propagation factor and heights for each ray traced in XO region to range r_{out}	dB,meters
propaf	Two-dimensional array, containing the propagation angles and factors for the direct and reflected rays (where applicable) for all output height/range points	radians, N/A
rloss	Propagation loss	dB

Table 134. EXTO SU save data element requirements.

Name	Description	Units
i_{rps}	Starting index counter for refractivity profiles	N/A
iz_e	Ending index in *curang*, *curng*, and *curht* to trace to r_{out}	N/A
iz_s	Starting index in *curang*, *curng*, and *curht* to trace to r_{out}	N/A

5.5 Return Grazing Angle (RET_GRAZE) CSC

The RET_GRAZE CSC interpolates grazing angles to every output range step r_{out}, and if propagation angles are desired everywhere (*lang* = '.true.'), the SU will also interpolate the propagation angles in height at every output range.

Upon entering the SU, if *lang* = '.true.', the two-dimensional array Θ_{rout}, is allocated and initialized. Θ_{rout} will contain all the interpolated propagation angles at each output height and every output range.

For every output range $rngout_i$ where i varies from 1 to n_{rout}, steps 1 through 2 are performed:

1. The grazing angle at the current output range is determined by referencing FN_PLINT:

$$\Psi_{rout_i} = \text{FN\_PLINT}\left(\Psi_{is}, \Psi_{isp1}, x\right),$$

where
$$is = \text{INT}\left(\frac{rngout_i}{\Delta r_{PE}}\right),$$
$$isp1 = \text{MIN}\left(is+1, i_{PE}\right),$$
$$x = \frac{rngout_i - is\Delta r_{grz}}{\Delta r_{grz}}.$$

If *lang* = '.true.', then the SU continues with step 2; otherwise, step 1 is repeated for all values of *i* to n_{rout}.

2. Parameters in calculating all propagation angles at the current output range are determined according to

$$ip = \text{INT}\left(\frac{rngout_i}{\Delta r_{grz}}\right),$$
$$ipp1 = \text{MIN}\left(ip+1, i_{gPE}\right),$$
$$x = \frac{rngout_i - ip\Delta r_{grz}}{\Delta r_{grz}}.$$

The propagation angles are then determined for all values of *in* from 1 to n_{ang} by referencing FN_PLINT:

$$\Theta rout_{in,i} = \textbf{FN\_PLINT}\left(\Theta p_{in,ip}, \Theta p_{in,ipp1}, x\right).$$

If the current value of Θ_p lies outside the PE calculation region (value = -999), *i* is incremented and step 2 is repeated for the next output range.

Finally, array Θ_p is deallocated before exiting.

Table 135 and Table 136 provide identification, description, units of measure, and the computational source for each RET_GRAZE CSC input and output data element.

Table 135. RET_GRAZE CSC input data element requirements.

Name	Description	Units	Source
Δr_{grz}	PE range step used for calculation of grazing angles	meters	APMINIT CSC
Δr_{PE}	PE range step	meters	PEINIT SU
i_{gPE}	Number of grazing angles computed from spectral estimation	N/A	GETANGLES SU
i_{PE}	Number of PE range steps	N/A	PEINIT SU
lang	Propagation angle and factor output flag '.true.'= Output propagation angle and propagation factor for direct and reflected ray (where applicable). '.false.' = Do not output propagation angles and factors	N/A	Calling CSCI
n_{ang}	Number of points in the vertical at which to spectrally estimate propagation angles.	N/A	GETANGLES SU
n_{rout}	Integer number of output range points desired	N/A	Calling CSCI
rngout	Array containing all desired output ranges	meters	APMINIT CSC
Ψ	Array of interpolated grazing angles at each PE range step	radians	GRAZE_INT SU
Θ_p	Two-dimensional array containing the propagation angle estimated from PE at n_{ang} height points and at every PE calculation range step during the initialization routine. Format is $\Theta_p\,(i,j)$ = propagation angle at the i^{th} height point (i=1 to n_{ang}) and j^{th} PE range step (j=0 to i_{gPE}).	radians	GETANGLES SU

Table 136. RET_GRAZE SU output data element requirements.

Name	Description	Units
Ψ_{rout}	Array of grazing angles at each output range r_{out}	radians
Θ_{rout}	Two-dimensional array containing the propagation angle spectrally estimated from PE at n_{ang} height points and at every output range step r_{out}	radians
i_{error}	Integer value that is returned if an error occurs in called routine	N/A

6. REQUIREMENTS TRACEABILITY

This section provides the traceability of the design of the APM CSCI Table 137 presents this traceability between the corresponding sections of the Software Requirements Specification (SRS) and the Software Design Description (SDD) and between the various components of the APM CSCI.

Table 137. Traceability Matrix between the SRS and the SDD.

Software Requirements Specification		Software Design Description	
SRS Requirement Name	SRS Paragraph Number	Software Design Description Name	SDD Paragraph Number
CSCI Capability Requirements	3.1	CSCI-WIDE DESIGN DECISIONS	3.
CSCI Capability Requirements	3.1	CSCI Components	4.1
CSCI Capability Requirements	3.1	Concept of Execution	4.2
Advance Propagation Initialization (APMINIT) CSC	3.1.1	Advance Propagation Initialization (APMINIT) CSC	5.1
Allocate Arrays APM (ALLARRAY_APM) SU	3.1.1.1	Allocate Arrays APM (ALLARRAY_APM) SU	5.1.1
Allocate Array PE (ALLARRAY_PE) SU	3.1.1.2	Allocate Array PE (ALLARRAY_PE) SU	5.1.2
Allocate Array RO (ALLARRAY_RO) SU	3.1.1.3	Allocate Array RO (ALLARRAY_RO) SU	5.1.3
Allocate Array (ALLARRAY_XORUF) SU	3.1.1.4	Allocate Array (ALLARRAY_XORUF) SU	5.1.4
Alpha Impedance Initialization (ALN_INIT) SU	3.1.1.5	Alpha Impedance Initialization (ALN_INIT) SU	5.1.5
Antenna Pattern (ANTPAT) SU	3.1.1.6	Antenna Pattern (ANTPAT) SU	5.1.6
APM Status (APMSTATUS) SU	3.1.1.7	APM Status (APMSTATUS) SU	5.1.7
Dielectric Initialization (DIEINIT) SU	3.1.1.8	Dielectric Initialization (DIEINIT) SU	5.1.8
FFT Parameters (FFTPAR) SU	3.1.1.9	FFT Parameters (FFTPAR) SU	5.1.9
Fill Height Arrays (FILLHT) SU	3.1.1.10	Fill Height Arrays (FILLHT) SU	5.1.10
Gaseous Absorption (GASABS) SU	3.1.1.11	Gaseous Absorption (GASABS) SU	5.1.11
Get Effective Earth Radius Factor (GET_K) SU	3.1.1.12	Get Effective Earth Radius Factor (GET_K) SU	5.1.12
Get Alpha Impedance (GETALN) SU	3.1.1.13	Get Alpha Impedance (GETALN) SU	5.1.13
Get Angles (GETANGLES) SU	3.1.1.14	Get Angles (GETANGLES) SU	5.1.14
Get Maximum Angle (GETTHMAX) SU	3.1.1.15	Get Maximum Angle (GETTHMAX) SU	5.1.15
Grazing Angle Interpolation (GRAZE_INT) SU	3.1.1.16	Grazing Angle Interpolation (GRAZE_INT) SU	5.1.16
Height Check (HTCHECK) SU	3.1.1.17	Height Check (HTCHECK) SU	5.1.17

Table 137. Traceability Matrix between the SRS and the SDD. (continued)

Software Requirements Specification		**Software Design Description**	
SRS Requirement Name	SRS Paragraph Number	Software Design Description Name	SDD Paragraph Number
Interpolate Profile (INTPROF) SU	3.1.1.18	Interpolate Profile (INTPROF) SU	5.1.18
PE Initialization (PEINIT) SU	3.1.1.19	PE Initialization (PEINIT) SU	5.1.19
Poly 4 (FN_POLY4) Function	3.1.1.20	Poly 4 (FN_POLY4) Function	5.1.20
Poly 5 (FN_POLY5) Function	3.1.1.21	Poly 5 (FN_POLY5) Function	5.1.21
Profile Reference (PROFREF) SU	3.1.1.22	Profile Reference (PROFREF) SU	5.1.22
Refractivity Initialization (RefInit) SU	3.1.1.23	Refractivity Initialization (REFINIT) SU	5.1.23
Remove Duplicate Refractivity Levels (REMDUP) SU	3.1.1.24	Remove Duplicate Refractivity Levels (REMDUP) SU	5.1.24
RG Trace (RGTRACE) SU	3.1.1.25	RG Trace (RGTRACE) SU	5.1.25
Terrain Initialization (TERINIT) SU	3.1.1.26	Terrain Initialization (TERINIT) SU	5.1.26
Trace to Output Range (TRACE_ROUT) SU	3.1.1.27	Trace to Output Range (TRACE_ROUT) SU	5.1.27
Trace to Next Step (TRACE_STEP) SU	3.1.1.28	Trace to Next Step (TRACE_STEP) SU	5.1.28
Troposcatter Initialization (TROPOINIT) SU	3.1.1.29	Troposcatter Initialization (TROPOINIT) SU	5.1.29
Starter Field Initialization (XYINIT) SU	3.1.1.30	Starter Field Initialization (XYINIT) SU	5.1.30
Advance Propagation Model Step (APMSTEP) CSC	3.1.2	Advance Propagation Model Step (APMSTEP) CSC	5.2
Calculate Propagation Loss (CALCLOS) SU	3.1.2.1	Calculate Propagation Loss (CALCLOS) SU	5.2.1
Current Wind (FN_CURWIND) Function	3.1.2.2	Current Wind (FN_CURWIND) Function	5.2.2
Dielectric Constant (FN_DIECON) Function	3.1.2.3	Dielectric Constant (FN_DIECON) Function	5.2.3
DOSHIFT SU	3.1.2.4	DOSHIFT SU	5.2.4
Discrete Sine/Cosine Fast Fourier Transform (DRST) SU	3.1.2.5	Discrete Sine/Cosine Fast Fourier Transform (DRST) SU	5.2.5

Table 137. Traceability Matrix between the SRS and the SDD. (continued)

Software Requirements Specification		**Software Design Description**	
SRS Requirement Name	SRS Paragraph Number	Software Design Description Name	SDD Paragraph Number
Flat Earth Direct Ray (FEDR) SU	3.1.2.6	Flat Earth Direct Ray (FEDR) SU	5.2.6
Flat Earth Model (FEM) SU	3.1.2.7	Flat Earth Model (FEM) SU	5.2.7
Fast Fourier Transform (FFT) SU	3.1.2.8	Fast-Fourier Transform (FFT) SU	5.2.8
Free Space Range Step (FRSTP) SU	3.1.2.9	Free Space Range Step (FRSTP) SU	5.2.9
FZLIM SU	3.1.2.10	FZLIM SU	5.2.10
Get Propagation Factor (FN_GETPFAC) Function	3.1.2.11	Get Propagation Factor (FN_GETPFAC) Function	5.2.11
Get Reflection Coefficient (GETREFCOEF) SU	3.1.2.12	Get Reflection Coefficient (GETREFCOEF) SU	5.2.12
Get Troposcatter Loss (FN_GET_TLOSS) Function	3.1.2.13	Get Troposcatter Loss (FN_GET_TLOSS) Function	5.2.13
Linear Interpolation (FN_PLINT) Function	3.1.2.14	Linear Interpolation (FN_PLINT) Function	5.2.14
Mixed Fourier Transform (MIXEDFT) SU	3.1.2.15	Mixed Fourier Transform (MIXEDFT) SU	5.2.15
Parabolic Equation Step (PESTEP) SU	3.1.2.16	Parabolic Equation Step (PESTEP) SU	5.2.16
Ray Trace (RAYTRACE) SU	3.1.2.17	Ray Trace (RAYTRACE) SU	5.2.17
Refractivity Interpolation (REFINTER) SU	3.1.2.18	Refractivity Interpolation (REFINTER) SU	5.2.18
Ray Optics Calculation (ROCALC) SU	3.1.2.19	Ray Optics Calculation (ROCALC) SU	5.2.19
Ray Optics Loss (ROLOSS) SU	3.1.2.20	Ray Optics Loss (ROLOSS) SU	5.2.20
Save Profile (SAVEPRO) SU	3.1.2.21	Save Profile (SAVEPRO) SU	5.2.21
Spectral Estimation (SPECEST) SU	3.1.2.22	Spectral Estimation (SPECEST) SU	5.2.22
Surface Impedance (SURFIMP) SU	3.1.2.23	Surface Impedance (SURFIMP) SU	5.2.23
Troposcatter (TROPOSCAT) SU	3.1.2.24	Troposcatter (TROPOSCAT) SU	5.2.24
Extended Optics Initialization (XOINIT) CSC	3.1.3	Extended Optics Initialization (XOINIT) CSC	5.3

Table 137. Traceability Matrix between the SRS and the SDD. (continued)

Software Requirements Specification		**Software Design Description**	
SRS Requirement Name	SRS Paragraph Number	Software Design Description Name	SDD Paragraph Number
Advanced Propagation Model Clean (APMCLEAN) CSC	3.1.3.1	Advanced Propagation Model Clean (APMCLEAN) CSC	5.3.1
Clutter-to-Noise (CLUTTER) SU	3.1.3.2	Clutter-to-Noise (CLUTTER) SU	5.3.2
Diffraction Loss (FN_DLOSS) Function)	3.1.3.3	Diffraction Loss (FN_DLOSS) Function)	5.3.3
Get Theta (GETTHETA) SU	3.1.3.4	Get Theta (GETTHETA) SU	5.3.4
GIT Initialization (GIT_INIT) SU	3.1.3.5	GIT Initialization (GIT_INIT) SU	5.3.5
GofZ (GOFZ) Function	3.1.3.6	GofZ (GOFZ) Function	5.3.6
Mean Filter (MEANFILT) SU	3.1.3.7	Mean Filter (MEANFILT) SU	5.3.7
Optical Region Limit (OPLIMIT) SU	3.1.3.8	Optical Region Limit (OPLIMIT) SU	5.3.8
Optical Difference (OPTICF) SU	3.1.3.9	Optical Difference (OPTICF) SU	5.3.9
R1 Iteration (R1ITER) SU	3.1.3.10	R1 Iteration (R1ITER) SU	5.3.10
Standard Propagation Model Initialization (SPM_INIT) SU	3.1.3.11	Standard Propagation Model Initialization (SPM_INIT) SU	5.3.11
Standard Propagation Model (SPM) SU	3.1.3.12	Standard Propagation Model (SPM) SU	5.3.12
Extended Optics Step (XOSTEP) CSC	3.1.4	Extended Optics Step (XOSTEP) CSC	5.4
Extended Optics (EXTO) SU	3.1.4.1	Extended Optics (EXTO) SU	5.4.1
Return Grazing Angle (RET_GRAZE) CSC	3.1.5	Return Grazing Angle (RET_GRAZE) CSC	5.5
CSCI External Interface Requirements	3.2	External Interface	4.3.2
CSCI Internal Interface Requirements	3.3	Internal Interface	4.3.3
CSCI Internal Data Requirements	3.4	Internal Data	4.3.4
Environmental Radio Refractivity field Data Element	3.5.1	Environmental Radio Refractivity field Data Element	7.2
Terrain Profile Data Element	3.5.2	Terrain Profile Data Element	7.3
Implementation and Application Considerations	3.10.1	Implementation and Application Considerations	7.1

7. NOTES

7.1 APM CSCI IMPLEMENTATION AND APPLICATION CONSIDERATIONS

The calling external CSCI application will determine the employment of the APM CSCI. However, the intensive computational nature of the APM CSCI must be considered when designing an efficient calling application. For this reason, the APM CSCI is designed with flexibility for various hardware suites and computer resource management considerations. This APM CSCI applies only to a coverage and loss diagram application. The following highly recommended guidelines are provided to aid in the design of a coverage or loss diagram application that will most efficiently employ the APM CSCI.

The APM CSCI propagation loss calculations are independent of any target or receiver considerations, therefore, for any EM emitter, one execution of the APM CSCI may be used to create both a coverage diagram and a loss diagram. Since execution time and computer memory allocation should be a consideration when employing this model, it is most efficient and appropriate to execute the APM CSCI for a particular EM system/environmental/terrain combination before executing any application. The output of the APM CSCI would be stored in a file that would be accessed by multiple applications.

For example, the external application operator may desire a coverage diagram for one particular radar system. At the beginning of the coverage diagram application, a check would be made for the existence of a previously created APM CSCI output file appropriate for the EM system, environmental, and terrain conditions. If such a file exists, the propagation loss values would be read from the file and used to create the coverage diagram. If the file does not exist, the APM CSCI would be executed to create one. As the APM CSCI is executing, its output could be routed simultaneously to a graphics display device and a file. This file could then be used in the loss diagram application should the operator also choose it. Two distinct applications, therefore, are achieved with only one execution of the APM CSCI. Additionally, should the operator desire an individual coverage diagram for each of multiple targets, or a single coverage diagram illustrating radar detection of a low-flying missile superimposed on a coverage diagram illustrating his own radar's vulnerability as defined by the missile's ESM receiver, only a single execution of the APM CSCI would be required, thereby saving valuable computer resources.

7.2 ENVIRONMENTAL RADIO REFRACTIVITY FIELD DATA ELEMENTS

The radio-refractivity field, i.e. the profiles of M-units versus height, should consist of vertical piece-wise linear profiles specified by couplets of height in meters with respect to mean sea level and modified refractivity (M-units) at multiple arbitrary ranges. All vertical profiles must contain the same number of vertical data points and be specified

such that each numbered data point corresponds to like-numbered points (i.e., features) in the other profiles. The first numbered data point of each profile must correspond to a height of zero mean sea level and the last numbered data point must correspond to a height such that the modified refractivity for all greater heights is well represented by extrapolation using the two highest profile points specified.

With the inclusion of terrain and allowing the terrain profile to fall below mean sea level, refractivity profiles can also be provided in which the first level is less than 0 (or below mean sea level). For a terrain profile that falls below mean sea level at some point, the assumption is that the minimum height may be less than the first height in any refractivity profile specified. Therefore, an extrapolation flag, i_{extra}, must be specified to indicate how the APM CSCI should extrapolate from the first refractivity level to the minimum height along the terrain profile. Setting i_{extra} to 0 will cause the APM CSCI to extrapolate to the minimum height using a standard atmosphere gradient; setting i_{extra} to 1 will cause the APM CSCI to extrapolate to the minimum height using the gradient determined from the first two levels of the refractivity profile.

Within each profile, each numbered data point must correspond to a height greater than or equal to the height of the previous data point. Note that this requirement allows for a profile which contains redundant data points. Note also that all significant features of the refractivity profiles must be specified, even if they are above the maximum output height specified for a particular application of APM.

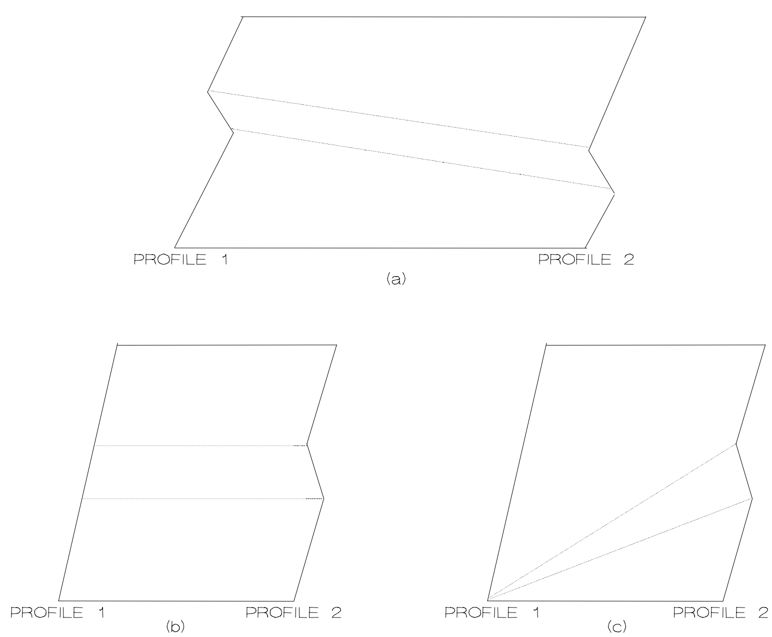

Figure 3. Idealized M-unit profiles (solid) and lines of interpolation (dashed).

The external CSCI application designer and the external application operator share responsibility for determining appropriate environmental inputs. For example, a loss diagram may be used to consider a surface-to-surface radar detection problem. Since the operator is interested in surface-to-surface, he/she may truncate the profile while assuming that effects from elevated ducting conditions are negligible. It may be, however, that the elevated duct does indeed produce a significant effect. The operator should ensure therefore that the maximum height of the profile allows for the inclusion of all significant refractive features.

This specification allows a complicated refractivity field to be described with a minimum of data points. For example, a field in which a single trapping layer linearly descends with increasing range can be described with just two profiles containing only four data points each, frame (a) of Figure 3. In the same manner, other evolutions of refractive layers may be described. Frames (b) and (c) of Figure 3 show two possible scenarios for the development of a trapping layer. The scenario of choice is the one that is consistent with the true thermodynamical and hydrological layering of the atmosphere.

Two external implementation data variables applicable to both the external application operator and to the calling application designer are r_{max}, the maximum APM CSCI output range, and h_{max}, the maximum APM CSCI output height. These two parameters are required by the APM CSCI to determine the horizontal and vertical resolution, respectively, for internal range and height calculations based on the current values of n_{rout} and n_{zout}. Any value of r_{max} and h_{max} is allowed for the convenience of the external application operator and the calling application designer, provided $r_{max} \geq 5$ km, and $h_{max} \geq 100$ m. For example, the external application operator may desire a coverage diagram that extends to a range of 500 kilometers (km). In addition to accommodating the desires of the operator, specification of such a convenient maximum range eases the burden for the application designer in determining incremental tick marks for the horizontal axis of the display.

Provided the value of the parameter *lerr12* is set to '.false.', if the furthest environment profile range is less than r_{max}, the APM CSCI will automatically create an environment profile at r_{max} equal to the last profile specified, making the environment homogeneous from the range of the last profile specified to r_{max}. For example, a profile is input with an accompanying range of 450 km. If the external application operator chooses an r_{max} of 500 km, the APM CSCI will continue loss calculations to 500 km, keeping the refractivity environment homogeneous from 450 km to 500 km.

If *lerr12* is set to '.true.' and the furthest environment profile range is less than r_{max}, then an error will be returned in i_{error} from the APMINIT CSC, which allows the external CSCI application designer greater flexibility in how environment data are handled.

7.3 TERRAIN PROFILE DATA ELEMENT

The terrain profile should consist of linear piecewise segments specified as range/height pairs. All range values must be increasing, and the first terrain height value must be at range zero. General ground composition types can be specified (Table 4), along with corresponding ranges over which the ground type is to be applied. If ground type "User Defined" is specified ($igrnd_i$ = 7), then numeric values of relative permittivity and conductivity must be given.

The maximum height, h_{max}, must always be greater than the minimum height, h_{min}. Also, a value of h_{max} must be given such that it is larger than the maximum elevation height along a specified terrain profile.

Provided *lerr6* is set to '.false.', if the furthest range point in the terrain profile is less than r_{max}, the APM CSCI will automatically create a height/range pair as part of the terrain profile at r_{max} with elevation height equal to the last height specified in the profile, making the terrain profile flat from the range of the last profile point specified to r_{max}. For example, a terrain profile is input where the last height/range pair is 50 m in height with an accompanying range of 95 km. If the external application operator chooses an r_{max} of 100 km, the APM CSCI will continue loss calculations to 100 km, keeping the terrain profile flat from 95 to 100 km with an elevation height of 50 m.

If *lerr6* is set to '.true.' and the furthest range point is less than r_{max}, then an error will be returned in i_{error} from the APMINIT SU, which allow the external CSCI application designer greater flexibility in how terrain data are handled.

7.4 ACRONYM AND ABBREVIATIONS

Table 138 is a glossary of acronyms and abbreviations used within this document.

Table 138. Acronyms and Abbreviations

Term	Definition
MIN	Minimum of variables within parenthesis
MAX	Maximum of variables within parenthesis
APM	Advanced Propagation Model
Centibel	One-hundredth of the logarithm of a quantity
COMMON BLOCK	Allows two or more FORTRAN SUs to share variables without having to pass them as arguments
COS	Cosine function
CMPLX	Data conversion to complex number

Table 138. Acronyms and Abbreviations. (continued)

Term	Definition
CSCI	Computer software configuration item
dB	Decibel
decibel	10 times the logarithm of a quantity
EM	electromagnetic
FE	Flat earth
FFT	Fast-Fourier Transform
FORTRAN	Formula Translation
IMAG	Imaginary part of complex number
INT	Integer value of
km	Kilometers
LOG_{10}	Logarithm to base 10
LN	Natural logarithm
m	Meters
M	Modified refractivity units
MHz	MegaHertz
M-unit	Refractivity measurement unit
μV/m	Microvolts per meter
N/A	Not applicable
NINT	Round real number
PE	Parabolic Equation
p space	Phase space
RADA1	Angle trace function
radian	Unit of angular measurement
REAL	Real part of complex number
RO	Ray Optics
SIGN	Sign transfer function
SIN	Sine function
SIN^{-1}	Inverse sine function
S/m	Conductivity unit Siemens per meter
Sin(X)/X	Sine(X)/X
SRS	Software Requirements Specification
SU	Software unit
TAN^{-1}	Inverse tangent function
z-space	Height space

7.5 SDD VARIABLE NAME, FORTRAN VARIABLE NAME CROSS REFERENCE

Table 139 is a cross reference of variable names used within the body of this document and the FORTRAN variable names as used in the APM CSCI source code. Included are the SDD variable name, its description, the FORTRAN source code name, and the designation of the FORTRAN COMMON BLOCK name, if applicable. Note that all dynamically allocated arrays are declared PUBLIC and are common to all SUs containing the APM_MOD module.

Table 139. Variable name cross reference.

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
a_0	Angle at start of ray trace step	a0	N/A
a_1	Angle at end of ray trace step	a1	N/A
a_2	Tangent angle for receiver height $zout_j$	ang2	N/A
a_{atz}	Local ray or propagation angle at height z_{lim} and range r_{atz}	aatz	APM_VAR
abs_{hum}	Absolute humidity near the surface	abshum	REFRACTIVITY
a_{crit}	Critical angle (angle above which no rays are trapped)	acrit	APM_VAR
a_{cut}	Tangent angle from antenna height to radio horizon	acut	APM_VAR
$adif$	Height differences between ant_{ref} and all output receiver heights	adif()	N/A
a_{ek}	Effective earth radius	aek	APM_VAR
a_{ekst}	4/3 effective earth's radius	aekst	N/A
$ainc_1$	Angular increment for ray tracing to determine grazing angles	ainc1	N/A
$ainc_2$	Angular increment for ray tracing to determine grazing angles	ainc2	N/A
$ainc_3$	Angular increment for ray tracing to determine grazing angles	ainc3	N/A
a_{launch}	Launch angle used which, when traced, separates PE and XO regions from the RO region	alaunch	APM_VAR
α	Source elevation angle	ang	N/A
α_d	Direct-path ray angle	alphad	APM_VAR
α_{dif}	The difference between current and previous outgoing propagation angles	angdif	N/A
α_{ld}	LOG of antenna pattern factor for α_d where α_d represents lowest direct ray angle in optical region	ald	N/A
α_{lim}	Elevation angle of the RO limiting ray	alflim	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
α_{pat}	Elevation angle relative to the antenna elevation angle	udif	N/A
α_r	Reflected-path ray angle	alphar	N/A
α_{ter}	Tangent angle from antenna height to current terrain height	alphax, terang	N/A
α_u	Maximum tangent ray angle from the source to the terrain peak along profile height	angu	N/A
$\alpha_{h,v}$	Surface impedance term for horizontal or vertical polarization	alphaq	APM_VAR
a_{mlim}	Elevation angle of RO limiting ray in radians. Used to initialize launch angle in the GETTHMAX SU	amlim	N/A
a_{mxcur}	Maximum local angle along the traced ray up to z_{lim} (with minimum limit a_{mlim})	amxcur	N/A
ant_{fac}	Antenna pattern parameter (depends on i_{pat} and μ_{bw})	afac	APM_VAR
ant_{ht}	Transmitting antenna height above local ground	antht	SYSTEMVAR
ant_{ko}	Height-gain value at source	antko	N/A
ant_{ref}	Transmitting antenna height relative to h_{minter}	antref	APM_VAR
a_s	Propagation angle for start of ray trace	as	N/A
$araft$	Array of angles after smoothing operation	araft()	N/A
$arbef$	Array of angles before smoothing operation	arbef()	N/A
a_{start}	Elevation angle at start of ray step	astart	N/A
a_{test}	Tangent angle used for automatic calculation of maximum propagation angle. Only used for modes i_{hybrid} = 0, 2.	atest	N/A
β	Terminal elevation angle	ab	N/A
β_d	Direct ray terminal elevation angle	betad	N/A
β_r	Reflected ray terminal elevation angle	betar	N/A
c_a	Wide-angle propagator correction term	cak	N/A
C_{1x}	Constant used to propagate c_{k1} by one range step in central difference algorithm	c1x	APM_VAR
C_{2x}	Constant used to propagate c_{k2} by one range step in central difference algorithm	c2x	APM_VAR
ck_1	Coefficient used in central difference form of DMFT	ck1	APM_VAR
ck_2	Coefficient used in central difference form of DMFT	ck2	APM_VAR
C_{lut}	Logical flag used to indicate if surface clutter calculations are desired.	clut	SYSTEMVAR
$cmft$	Coefficient used in backward difference form of DMFT	cmft	APM_VAR
$cmft_x$	Constant used to propagate $cmft$ by one range step in backward difference algorithm	cmft_x	APM_VAR
CNR	Clutter-to-Noise ratio array	cnr_dB()	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
c_o	Speed of light (299.79 x 10^{-6} m/s)	c0	N/A
con	$10^{-6}k_o$	con	APM_VAR
cn_{p75}	Factor used in calculating *filtp* array	cnp75	N/A
ct_1	Quantity defined in equ. 124 in EREPS 3.0 User's Manual NRaD TD 2648, pp. 106	ct1	N/A
ct_2	Quantity defined in equ. 125 in EREPS 3.0 User's Manual NRaD TD 2648, pp. 106	ct2	N/A
curang	Array of current local angles for each ray being traced in XO region	curang()	N/A
curht	Array of current local heights for each ray being traced in XO region	curht()	N/A
curng	Array of current local ranges for each ray being traced in XO region	curng()	N/A
ΔFd_{lo}^2	Difference in direct ray magnitude along Δx_{RO} below desired APM output point	dfsdlo	N/A
ΔFd_{hi}^2	Difference in direct ray magnitude along Δx_{RO} above desired APM output point	dfsdhi	N/A
ΔFr_{lo}^2	Difference in reflected ray magnitude along Δx_{RO} below desired APM output point	dfsrlo	N/A
ΔFr_{hi}^2	Difference in reflected ray magnitude along Δx_{RO} above desired APM output point	dfsrhi	N/A
ΔH_o	Frequency gain function correction term defined in equ. 127 in EREPS 3.0 User's Manual NRaD TD 2648, pp. 106	delho	N/A
$\Delta\Omega_{hi}$	Difference in total phase lag angle along Δx_{RO} above desired APM output point	danghi	N/A
$\Delta\Omega_{lo}$	Difference in total phase lag angle along Δx_{RO} below desired APM output point	danglo	N/A
Δp	Mesh size in angle- (or p-) space	delp	APM_VAR
Δr_{grz}	PE range step used for calculation of grazing angles	drgrz	APM_VAR
Δr_{out}	Output range step	drout	APM_VAR
Δr_{PE}	PE range step	dr	APM_VAR
Δr_{PE2}	½ PE range step	dr2	APM_VAR
Δr_{temp}	Range step for ray tracing	drtemp	N/A
$\Delta\theta$	Angle difference between mesh points in p-space	dtheta	APM_VAR
Δx_{RO}	RO range interval	delxRO	APM_VAR
Δz_{out}	Output height increment	dzout	APM_VAR
Δz_{PE}	PE mesh height increment (bin width in z-space)	delz	APM_VAR
d_1	Range from source to tangent point	d1	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
d_2	Range from receiver to tangent point	d2	N/A
$d2s$	Array of tangent ranges for all output receiver heights over smooth surface	d2s()	N/A
$d\alpha$	½ μ_{bwr}	dalpha	N/A
$dielec$	Two-dimensional array containing the relative permittivity and conductivity; $dielec_{1,i}$ and $dielec_{2,i}$, respectively.	dielec(,)	N/A
$dxd\alpha$	Derivative of range with respect to elevation angle	dxda	N/A
$dxd\alpha_d$	Derivative of range with respect to α_d	dxdad	N/A
$dxd\alpha_r$	Derivative of range with respect to α_r	dxdar	N/A
$dzd\alpha_d$	Derivative of height with respect to α_d	dzdad	N/A
$dzd\alpha_r$	Derivative of height with respect to α_r	dzdar	N/A
e_k	Effective earth's radius factor	ek	APM_VAR
$envpr$	Complex [refractivity] phase term array	envpr()	N/A
ε_r	Relative permittivity	epsilon	N/A
η_s	Quantity defined in equ. 126 in EREPS 3.0 User's Manual NRaD TD 2648, pp. 106	etas	N/A
$f(\alpha)$	Antenna pattern factor for angle α	patfac	N/A
$f(\vartheta_1)$	Antenna pattern factor for angle ϑ_1	factr	N/A
$f(\alpha_d)$	Antenna pattern factor for direct ray	facd	N/A
$f(-\alpha_r)$	Antenna pattern factor for reflected ray	facr	N/A
$farray$	Field array to be propagated one range step in free space	farray()	N/A
Fd^2	Magnitude array, direct ray	dmagsq(,)	APM_VAR
F_{dB}	Propagation factor in dB	ff, facdb	N/A
F_{dBlst}	Propagation factor in dB at previous range	pfdblst	N/A
$ffat1m$	Propagation factor array computed at 1 m above the surface.	ffat1m_dB()	N/A
$ffacz$	Two-dimensional array containing propagation factor, range, and propagation angle at z_{lim}	ffacz(,)	N/A
$ffrout$	Array of propagation factors at each output range beyond r_{atz} and at height z_{lim}	ffrout()	N/A
$filt$	Cosine-tapered (Tukey) filter array	filt()	N/A
$filtp$	Array filter for spectral estimation calculations	filtp()	N/A
f_{MHz}	Frequency in MHz	freq	SYSTEMVAR
f_{rqg}	Frequency in MHz at which to perform grazing angle calculations	frqg	N/A
f_{norm}	Normalization factor	fnorm	APM_VAR
f_r	Fractional bin used for interpolation	fr	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
Fr^2	Magnitude array, reflected ray	rmagsq(,)	APM_VAR
$frac_{RO}$	RO range interval fraction (0.0 to 0.25)	fracRO	N/A
Fr_{atz}	Propagation factor in dB at range r_{atz} and height z_{lim}	pfratz	N/A
$frsp$	Complex free space propagator term array	frsp()	N/A
f_{sum}^{2}	Square of coherent sum of directand reflected rays	ffac2	N/A
f_{ter}	Logical flag indicating if terrain profile has been specified: .true. = terrain profile specified .false. = terrain profile not specified	fter	APM_VAR
fv	Fraction range for profile interpolation	fv	N/A
γ_a	Surface specific attenuation	gammaa	REFRACTIVITY
γc	Dynamically allocated array of constants describing the backscattering effectiveness of the surface	gammac()	TERRAIN
γ_o	Oxygen absorption	gammao	N/A
γrng	Dynamically allocated array of ranges corresponding to the values in γc	gamrng()	TERRAIN
γ_w	Water absorption	gammaw	N/A
$\Gamma_{h,v}$	Complex reflection coefficient for horizontal or vertical polarization	refcoef	N/A
G	Gain of transmit/receive antennas	antgain	SYSTEMVAR
gas_{att}	Gaseous absorption attenuation rate	gasatt	APM_VAR
gas_{loss}	Gaseous absorption loss at range r_{out}	gasloss	APM_VAR
gr	Intermediate M-unit gradient array, RO region	gr()	N/A
$grad$	Two-dimensional array containing gradients of each profile used in XO calculations	grad(,)	N/A
g_{rd}	Refractivity gradient	grd	N/A
$grdum$	Array of refractivity gradients defined by profile $htdum$ and $refdum$	grdum()	N/A
h_0	Height at start of ray trace step	h0	N/A
h_1	Height at end of ray trace step	h1	N/A
H_1	Quantity defined in equ. 120 in EREPS 3.0 User's Manual NRaD TD 2648, pp. 106	hor1	N/A
H_2	Quantity defined in equ. 121 in EREPS 3.0 User's Manual NRaD TD 2648, pp. 106	hor2	N/A
$hfang$	Cut-back angles in degrees	hfang()	N/A
$hfangr$	Array of height-finder cut-back angles in radians	hfangr()	N/A
$hffac$	Cut-back antenna pattern factors	hffac()	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
HF_{flag}	HF computation flag indicating the frequency specified is less than 50 MHz	hf_flag	APM_VAR
h_{large}	Maximum height limit for last level in height/refractivity profiles	hlarge	N/A
$hlim$	Array containing the height at each output range separating the RO region from the PE (at close ranges) and XO (at far ranges) regions	hlim()	N/A
h_{max}	Maximum output height with respect to mean sea level	hmax	INPUTVAR
h_{min}	Minimum output height with respect to mean sea level	hmin	INPUTVAR
h_{minter}	Minimum height of terrain profile	hminter	APM_VAR
hm_{ref}	Height relative to h_{minter}	hmref	APM_VAR
$hmsl$	Two-dimensional array containing heights with respect to mean sea level of each profile. Array format must be $hmsl_{i,j}$ = height of i^{th} level of j^{th} profile; j=1 for range-independent cases	hmsl(,)	N/A
h_o	Effective scattering height - defined in equ. 109 in EREPS 3.0 User's Manual NRaD TD 2648, pp. 105	h0	N/A
H_o	Frequency gain function defined in equ. 119 in EREPS 3.0 User's Manual NRaD TD 2648, pp. 106	bigh	N/A
$href$	Heights of refractivity profile with respect to y_{ref}	href()	N/A
h_s	Height for start of ray trace	hs	N/A
h_{start}	Starting height for ray trace to fill array $hlim$	hstart	N/A
ht	PE mesh height array of size n_{fft}	ht()	N/A
$htdum$	Height array for current interpolated profile	htdum()	N/A
$htemp$	Heights at which ray is traced to every range in $rtemp$	htemp()	APM_VAR
h_{ter}	Height of terrain at end of ray trace step	hter	N/A
h_{termax}	Maximum terrain height along profile path	htermax	N/A
h_{test}	Minimum height at which all trapping refractivity features are below	htest	N/A
$htfe$	Array containing the height at each output range separating the FE region from the RO region (full hybrid mode), or the FE region from the PE region (partial hybrid mode)	htfe()	N/A
h_{thick}	Thickness of highest trapping layer from all refractivity profiles	hthick	N/A
ht_{lim}	Maximum height relative to h_{minter}	htlim	APM_VAR
htr	Two-dimensional array containing heights of each profile used in XO calculations	htr()	N/A
h_{trap}	Height of highest trapping layer from all refractivity profiles	htrap	N/A
ht_{ydif}	ht_{lim} - y_{fref}	htydif	APM_VAR

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
i_{alg}	Integer flag indicating which DMFT algorithm is being used: 0 = no DMFT algorithm will be used 1 = use central difference algorithm 2 = use backward difference algorithm	ialg	APM_VAR
i_{ap}	Index indicating when the local ray angle becomes positive in array *raya*	iap	APM_VAR
i_{err}	Return error code	ierr	N/A
i_{error}	Error flag – traps for various errors dependent on the calling SU	ierror	N/A
i_{extra}	Extrapolation flag for refractivity profiles entered in combination with terrain below below mean sea level 0 = extrapolate to minimum terrain height standard atmosphere gradient 1= extrapolate to minimum terrain height using first gradient in profile	iextra	REFRACTIVITY
i_{flag}	Flag indicating whether to determine maximum FFT size n_{fft} based on given Θ_{max} and z_{lim} or determine z_{lim} based on given Θ_{max} and FFT size n_{fft}.	iflag	N/A
i_{flag}	Flag to indicate which transform to perform 0 = cosine transform 1 = sine transform -1 = deallocates all allocated arrays	iflag	N/A
i_{flag}	Integer flag indicating what region reflection coefficient is being computed 0 = FE and RO regions 1 = PE region	iflag	N/A
i_g	Counter indicating current ground type being modeled	ig	APM_VAR
i_{gc}	Number of γc values for a particular application of APM	igc	TERRAIN
i_{gPE}	Number of grazing angles computed from spectral estimation	igpe	APM_VAR
i_{gr}	Number of different ground types specified	igr	TERRAIN
i_{grad}	Index of current gradient level in *grad*	igrad	N/A
igrd	Integer indexes indicating at what refractive gradient level to begin ray tracing for next XO range step for each ray in XO region	igrd()	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
igrnd	Integer array containing ground type composition for given terrain profile - can vary with range. Different ground types are: 0 = seawater 1 = freshwater 2 = wet ground 3 = medium dry ground 4 = very dry ground 5 = ice at -1 degree C 6 = ice at -10 degree C 7 = user-defined (in which case, values of relative permittivity and conductivity must be given).	igrnd()	N/A
i_{grz}	Number of grazing angles computed from ray trace	igrz	APM_VAR
i_{hmx}	Output range step index where height ht_{lim} is reached in array *hlim*	ihmx	APM_VAR
i_{hybrid}	Integer indicating which sub-models will be used: 0 = pure PE model 1 = full hybrid model (PE + FE + RO + XO) 2 = partial hybrid model (PE + XO)	ihybrid	APM_VAR
i_o	Starting index for *mpfl* array: 0 = 1st calculated output point is at surface 1 = 1st calculated output point is at height Δz_{out}	io	APM_VAR
i_{org}	Integer flag indicating origin of calling SU 0 = called from APMINIT CSC 1 = called from TROPOINIT SU	iorg	N/A
i_{p1}	First output height point index in *zout* where propagation loss will be computed at previous PE range	ip1	N/A
i_{p2}	First output height point index in *zout* where propagation loss will be computed at current PE range	ip2	N/A
i_{pat}	Antenna pattern type 1 = Omni-directional 2 = Gaussian 3 = Sine(x)/x 4 = Cosecant-squared 5 = Generic height-finder 6 = User-defined height-finder 7 = User-defined antenna pattern 8 = Quarter-wave vertical dipole (should be used only for HF applications)	ipat	SYSTEMVAR
i_{PE}	Number of PE range steps	ipe	APM_VAR
i_{peak}	Bin # in spectr corresponding to the peak magnitude	ipeak	N/A
i_{PEstp}	Counter indicating current PE range step	ipestp	N/A
i_{pl}	Polarization flag 0 = horizontal 1 = vertical	ipl	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
i_{pol}	Polarization flag: 0 = horizontal polarization 1 = vertical polarization	ipol	SYSTEMVAR
i_{quit}	Integer flag indicating to quit tracing current ray and begin again with a new launch angle	iquit	N/A
i_{ratz}	Index of output range step in which to begin storing propagation factor and outgoing angle for XO region	iratz	APM_VAR
i_{ROn}	Array index for next range in RO region	iROn	APM_VAR
i_{ROp}	Array index for previous range in RO region	iROp	APM_VAR
i_{rp}	Counter for current refractivity/gradient profile being used from *grad*	irp	N/A
i_{rps}	Starting index counter for refractivity profiles	irps	N/A
i_{rtemp}	Temporary number of range steps (used for ray tracing)	irtemp	N/A
i_s	Counter for current profile	is	APM_VAR
i_{start}	Array index for height in RO region corresponding to ant_{ref}	istart	APM_VAR
i_{start1}	Refractivity level index within *htdum* at ant_{ref}	istart1	APM_VAR
i_{stp}	Current output range step index	istp	N/A
i_{sz}	Number of points over which to perform average smoothing	isz	N/A
i_{tp}	Number of height/range points in profile	itp	TERRAIN
i_{tpa}	Number of height/range points pairs in profile *tx*, *ty*	itpa	APM_VAR
i_{type}	Ray type (direct or reflected) flag 0 = direct 1 = reflected	itype	N/A
i_{xo}	Number of range steps in XO calculation region	ixo	APM_VAR
i_{xostp}	Current output range step index for XO calculations	ixostp	N/A
iz	Number of propagation factor, range, angle triplets stored in *ffacz*	iz	APM_VAR
i_{zg}	Number of output height points corresponding to local ground height at current output range rout	izg	APM_VAR
iz_{inc}	Integer increment for storing points at top of PE region (i.e., points are stored at every iz_{inc} range step)	izinc	APM_VAR
iz_{max}	Maximum number of points allocated for arrays associated with XO calculations	izmax	APM_VAR
j_{ae}	Ending index within *mpfl* of airborne loss values	jae	N/A
j_{as}	Starting index within *mpfl* of airborne loss values	jas	N/A
j_e	Ending receiver height index at which to compute troposcatter loss	je	N/A
j_{end}	Index at which valid loss values in *mpfl* end	jend	N/A
j_{fe}	Ending index within *mpfl* of FE loss values	jfe	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
j_{fs}	Starting index within *mpfl* of FE loss values	jfs	N/A
j_{max}	Array index for maximum output height in RO region	jmax	N/A
j_{min}	Array index for minimum output height in RO region	jmin	N/A
j_{pe}	Ending index within *mpfl* of PE loss values	jpe	N/A
j_{ps}	Starting index within *mpfl* of PE loss values	jps	N/A
j_{re}	Ending index within *mpfl* of RO loss values	jre	N/A
j_{rs}	Starting index within *mpfl* of RO loss values	jrs	N/A
j_s	Refractive profile index for start of ray trace	js	N/A
j_s	Starting receiver height index at which to compute troposcatter loss	js	N/A
j_{start}	Index at which valid loss values in *mpfl* start	jstart	N/A
$jt2$	Index counter for *tx* and *ty* arrays indicating location of receiver range	jt2	APM_VAR
j_{xe}	Index at which valid loss values in *mpfl* end	jxe	N/A
j_{xs}	Index at which valid loss values in *mpfl* start	jxs	N/A
j_{xstart}	Starting index within *mpfl* of XO loss values	jxstart	N/A
jz_{lim}	PE bin # corresponding to z_{lim}, i.e., $z_{lim} = jz_{lim}\, \Delta z_{PE}$	jzlim	APM_VAR
k_{abs}	Gaseous absorption calculation flag: 0 = no absorption loss 1 = compute absorption loss based on air temperature t_{air} and absolute humidity abs_{hum} 2 = compute absorption loss based on specified absorption attenuation rate γ_a	kabs	N/A
k_{bin}	Number of bins complex PE field is to be shifted	kbin	N/A
k_{hi}	*k* index above desired point	khi	N/A
k_{lo}	*k* index below desired point	klo	N/A
k_{max}	Array index for maximum angle in RO region at range x_{ROn}	kmax	APM_VAR
k_{minn}	Array index for minimum angle in RO region at range x_{ROn}	kminn	APM_VAR
k_{minp}	Array index for minimum angle in RO region at range x_{ROp}	kminp	APM_VAR
k_o	Free-space wavenumber	fko	APM_VAR
k_{temp}	Temporary k_{lo} value	klotmp	N/A
λ	Wavelength	wl	APM_VAR
L	Propagation loss	dloss	N/A
lang	Propagation angle and factor output flag '.true.'= Output propagation angle and propagation factor for direct and reflected ray (where applicable). '.false.' = Do not output propagation angles and factors	lang	INPUT_VAR
L_{dif}	Difference between propagation loss and troposcatter loss	dif	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
l_{duct}	Logical flag indicating if surface-based duct profile has been specified '.true'. = surface-based duct exists '.false.' = no surface-based duct exists	lduct	APM_VAR
lerr6	User-provided error flag that will trap on certain errors if set to '.true.'	lerr6	ERRORFLAG
lerr12	User-provided error flag that will trap on certain errors if set to '.true.'	lerr12	ERRORFLAG
l_{evap}	Logical flag indicating if evaporation duct profile has been specified '.true'. = evaporation duct exists '.false.' = no evaporation duct exists	levap	APM_VAR
levels	Number of levels in *gr*, *q* and *zrt* arrays	levels	APM_VAR
L_{fs}	Free space loss	fsloss	N/A
l_{graze}	Logical flag indicating if grazing angles were computed for a particular application of APM	lgraze	N/A
l_{new}	Temporary refractivity level counter	newl	N/A
ln_{fft}	Power of 2 transform size, i.e. $n_{fft}=2^{ln_{fft}}$	ln	APM_VAR
ln_{min}	Minimum power of 2 transform size	lnmin	APM_VAR
ln_p	Power of 2 transform size used in spectral estimation calculations; i.e., $n_p = 2^{ln_p}$	lnp	APM_VAR
L_{sys}	Miscellaneous system losses	sysloss	SYSTEMVAR
lvl	Number of height levels in each profile used in XO calculations	lvl()	N/A
lvlep	Number of height/refractivity levels in profile *refdum* and *htdum*	lvlep	APM_VAR
lvlp	Number of height/refractivity levels in profiles	lvlp	REFRACTIVITY
m	Size of array *arbef*	m	N/A
mpfl	Two-dimensional propagation factor and loss array	mpfl	N/A
mpfl_rtg	Propagation loss and factor at receiver heights specified in the *zout_rtg* array	mpfl_rtg	N/A
μ_o	Antenna elevation angle in degrees	elev	SYSTEMVAR
μ_{or}	Antenna pattern elevation angle in radians	elv	APM_VAR
μ_{bw}	Antenna vertical beamwidth in degrees	bwidth	SYSTEMVAR
μ_{bwr}	Antenna vertical beamwidth in radians	bw	APM_VAR
μ_{lim}	Limiting elevation angle - no more than 10°	elv_lim	N/A
μ_{max}	Limiting angle for Sin(X)/X and generic height finder antenna pattern factors	umax	APM_VAR
n_{34}	¾ n_{fft}	n34	APM_VAR

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
n_4	¼ n_{fft}	nf4	APM_VAR
n_{ang}	Number of points in the vertical at which to spectrally estimate propagation angles	nang	APM_VAR
nc^2	Array of complex dielectric constants	cn2()	N/A
N_f	Noise figure	qnoisef	SYSTEMVAR
n_{fft}	Transform size	n	APM_VAR
n_{facs}	Number of user-defined cut-back angles and cut-back pattern factors	nfacs	SYSTEMVAR
$nlvl$	Number of levels in new profile	nlvl	APM_VAR
n_{m1}	n_{fft} -1	nm1	APM_VAR
no_{PE}	Integer flag indicating if PE calculations are needed: 0 = PE calculations needed 1 = no PE calculations needed	nope	APM_VAR
n_{p34}	¾ n_p	np34	APM_VAR
n_{p4}	¼ n_p	np4	APM_VAR
n_p	Number of bins in upper PE region to consider for spectral estimation	npnts	APM_VAR
n_{prof}	Number of refractivity profiles	nprof	REFRACTIVITY
n_{ray}	Number of rays used for ray trace to determine grazing angles	nray	N/A
n_{rout}	Integer number of output range points desired	nrout	INPUTVAR
n_s	Transform size for spectral estimation calculations	ns	APM_VAR
n_{xo}	Number of rays traced, i.e., height points, in XO region	nxo	N/A
n_{zout}	Integer number of output height points desired	nzout	INPUTVAR
n_{zout_rtg}	Number of height output points for receiver heights relative to the local ground elevation.	nzout_rtg	INPUTVAR
n_w	Number of wind speeds	nw	REFRACTIVITY
Ω	Total phase angle	phdif	N/A
Ω	Total phase angle array	omega(,)	N/A
ω_s	Interpolated wind speed	ws, windsp	N/A
PE_{flag}	Flag to indicate use of PE algorithm only: '.true.' = only use PE sub-model '.false.' = use automatic hybrid model	peflag	INPUTVAR
p_{elev}	Sine of antenna elevation angle	pelev	APM_VAR
φ	Phase lag angle of reflected ray	rphase	N/A
pl_{cnst}	Constant used in determining propagation loss (pl_{cnst} = 20 $\log_{10}(2\ k_o)$)	plcnst	APM_VAR
pl_d	Path length difference from range x for direct ray	pld	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
pl_r	Path length difference from range x for reflected ray	plr	N/A
p_{mag}	Interpolated magnitude of complex PE field	pmag	N/A
$prfhxo$	Two-dimensional array of propagation factor and heights for each ray traced in XO region to range r_{out}	prfh_xo	N/A
$profint$	Profile interpolated to every Δz_{PE} in height	profint()	N/A
$propaf$	Two-dimensional array, containing the propagation angles and factors for the direct and reflected rays (where applicable) for all output height/range points	propaf()	N/A
P_t	Transmitter peak power	tx_pow	SYSTEMVAR
ψ	Grazing angle	psi, angle	N/A
Ψ	Array of interpolated grazing angles at each PE range step	graze()	N/A
Ψ_{rout}	Array of grazing angles at each output range r_{out}	graze_at_rout()	N/A
ψ_{lim}	Grazing angle of limiting ray	psilim	APM_VAR
ψ_{PE}	Array containing grazing angles computed from spectral estimation of PE field	grz_pe()	N/A
ψ_{ray}	Two-dimensional array containing grazing angles and corresponding ranges computed from ray trace	grz_ray(,)	N/A
q	Intermediate M-unit difference array, RO region	q()	N/A
q_t	Quantity defined in equ. 128 in EREPS 3.0 User's Manual NRaD TD 2648, pp. 107	qt	N/A
r	Current PE range	r	N/A
r_0	Range at start of ray trace step	r0	N/A
r_1	Range at end of ray trace step	r1	N/A
r_1	Path length for direct-ray path	r1	N/A
r_1	Quantity defined in equ. 122 in EREPS 3.0 User's Manual NRaD TD 2648, pp. 106	r1	N/A
r_2	Path length for reflected-ray path	r2	N/A
r_2	Quantity defined in equ. 123 in EREPS 3.0 User's Manual NRaD TD 2648, pp. 106	r2	N/A
r_{ange}	Range for profile interpolation	range	N/A
$ratio$	Fractional range term used for interpolation	ratiox	N/A
$ratio_k$	Fraction of one k index (0 to 1)	ratiok	N/A
r_{atz}	Range at which z_{lim} is reached (used for hybrid model)	ratz	APM_VAR
$raya$	Array containing all local angles of traced ray a_{launch} at each i_{rtemp} range	raya()	APM_VAR
r_{crit}	Minimum M-unit value above height ant_{ref}	rcrit	N/A
$rdif_1$	Range difference between adjacent terrain points	rdif1	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
$rdif_2$	Range difference between adjacent terrain points	rdif2	N/A
r_{difsum}	Sum of adjacent terrain point differences	rdifsum	N/A
rdt	Array of minimum ranges at which diffraction field solutions are applicable (for smooth surface) for all output receiver heights	rdt()	N/A
$refdum$	M-unit array for current interpolated profile	refdum()	N/A
$refmsl$	Two-dimensional array containing refractivity with respect to mean sea level of each profile. Array format must be $refmsl_{i,j}$ = M-unit at i^{th} level of j^{th} profile; j=1 for range-independent cases	refmsl(,)	N/A
$refref$	Refractivity profile with respect to y_{ref}	refref()	N/A
r_f	Constant used for troposcatter calculations	rf	APM_VAR
$rfac1$	Propagation factor at valid output height points from PE field at range r_{last}	rfac1()	N/A
$rfac2$	Propagation factor at valid output height points from PE field at range r	rfac2()	N/A
r_{fix}	Fixed range increment of terrain profile	rfix	N/A
r_{flat}	Maximum range at which the terrain profile remains flat from the source	rflat	N/A
r_{frac}	Ratio between adjacent terrain point differences	rfrac	N/A
$rgrnd$	Array containing ranges at which varying ground types apply	rgrnd()	N/A
r_{hor}	Radio horizon range	rhor	APM_VAR
r_{hor1}	Minimum range at which diffraction field solutions are applicable - determined for 0 receiver height	rdhor1	APM_VAR
R_k	Constant used to compute coefficients in central difference form of the DMFT	rk	APM_VAR
r_{last}	Previous PE range	rlast	N/A
r_{log}	10 $\log_{10}$(PE range r)	rlog	APM_VAR
$rlogo$	Array containing 20 times the logarithm of all output ranges	rlogo()	N/A
r_{loglst}	10 $\log_{10}$(previous PE range r_{last})	rloglst	APM_VAR
$rloss$	Propagation loss	rloss()	N/A
$rloss\_rtg$	Propagation loss computed relative to the local ground height at heights specified by $zout\_rtg$	rloss_rtg()	N/A
rm	Intermediate M-unit array, RO region	rm()	N/A
R_{mag}	Magnitude of reflection coefficient	rmag	N/A
r_{max}	Maximum specified range	rmax	INPUTVAR
r_{mid}	Range at which interpolation for range-dependent profiles is performed	rmid	N/A
rm_{max}	Maximum M-unit value of refractivity profile at range 0	rmmax	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
rm_{min}	Minimum M-unit value of refractivity profile at range 0	rmmin	N/A
rm_{tx}	M-unit value at height ant_{ref}	rmtx	APM_VAR
r_{mult}	PE range step multiplication factor	rmult	INPUTVAR
rn	Array of R_T to the i^{th} power (e.g., $rn_i = R_T^i$)	rn()	N/A
$rngout$	Array containing all desired output ranges	rngout()	N/A
$rngprof$	Ranges of each profile: $rngprof_i$ = range of i^{th} profile	rngprof()	N/A
$rngwind$	Ranges of wind speeds entered: $rngwind_i$ = range of i^{th} wind speed	rngwind()	N/A
r_o	Current ending range for ray trace step	ro	N/A
$RO\alpha_{dir}$	Array of propagation angles of direct rays determined in the RO region	ROdir_ang()	APM_VAR
$RO\alpha_{ref}$	Array of propagation angles of reflected rays determined in the RO region	ROref_ang()	APM_VAR
r_{out}	Current output range	rout	N/A
r_{pest}	Range at which PE loss values will start being calculated	rpest	APM_VAR
r_s	Range for start of ray trace	rs	N/A
r_{skip}	Approximate range interval of skip zone if duct is present	rskip	N/A
r_{slope}	Ray slope used in determining reflection point over terrain	rslope	N/A
r_{sq}	Square of current output range	rsq	N/A
r_{sqk}	Earth curvature correction factor	rsqk	N/A
$rsqrd$	Array containing the square of all desired output ranges	rsqrd()	N/A
R_T	Complex root of quadratic equation for mixed transform method based on Kuttler's formulation	rt	APM_VAR
rt_1	r_f multiplied by ant_{ref}	r1t	APM_VAR
$rtemp$	Range steps for tracing to determine maximum PE angle	rtemp()	APM_VAR
r_{tst}	Range at which to begin RO calculations (equal to 2.5 km)	rtst	N/A
ruf	Logical flag indicating if rough sea surface calculations are required '.true.' = perform rough sea surface calculations '.false.' = do not perform rough sea surface calculations	ruf	APM_VAR
ruf_{fac}	Factor used for wave height calculation	ruf_fac	APM_VAR
ruf_{ht}	Sea surface rms wave height	ruf_ht	APM_VAR
rv_1	Range of the previous refractivity profile	rv1	N/A
rv_2	Range of the next refractivity profile	rv2	APM_VAR
σ	Conductivity	sigma	N/A
s	Quantity defined equ. 110 in EREPS 3.0 User's Manual NRaD TD 2648, pp. 105	s	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
s_{bw}	Sine of antenna vertical beam width	sbw	APM_VAR
s_{gain}	Normalization factor used in starter field calculation	sgain	N/A
slp	Slope of each segment of terrain	slp()	N/A
sn_1	Term used in troposcatter loss calculation	sn1	N/A
$snref$	Surface refractivity	snref	N/A
$snref_0$	Surface refractivity taken from the refractivity profile with respect to mean sea level	snref_0	APM_VAR
$snref_{tx}$	Surface refractivity at transmitter	snref_tx	APM_VAR
$spectr$	Spectral amplitude of field	spectr()	N/A
$\vartheta 0$	Array of angles used to determine common volume scattering angle	theta0()	N/A
ϑ_1	Tangent angle from source height	theta1	N/A
ϑ_2	Tangent angle from receiver height	theta2	N/A
$\vartheta 1_s$	Tangent angle from source (for smooth surface)	theta1s	APM_VAR
$\vartheta 2s$	Array of tangent angles from all output receiver heights - used with smooth surface	theta2s()	N/A
$\vartheta 1t$	Array of tangent angles from source height - used with terrain profile	th1()	N/A
θ_{hbw}	Antenna horizontal beam width	horbw	SYSTEMVAR
Θ_{max}	Maximum propagation angle in PE calculations	thetamax	N/A
ϑ_{mxg}	Maximum PE calculation angle for spectral estimation of grazing angles	thmxg	N/A
Θ_{75}	75% of maximum propagation angle in PE calculations	theta75	APM_VAR
ϑ_{out}	Outgoing propagation angle determined at top of PE region	thout	N/A
θ	Common volume scattering angle	theta	N/A
Θ_{rout}	Two-dimensional array containing the propagation angle spectrally estimated from PE at n_{ang} height points and at every output range step r_{out}	ptheta_rout(,)	N/A
Θ_p	Two-dimensional array containing the propagation angle estimated from PE at n_{ang} height points and at every PE calculation range step during the initialization routine.	ptheta(,)	N/A
θ_t	Angular interval limit for ray trace in determining grazing angles	degt	N/A
t_{air}	Air temperature near the surface	tair	REFRACTIVITY
τ	Pulse length/width	pulse_len	SYSTEMVAR
$tang$	Tangent of angle array from terrain slopes.	tang()	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
$terx$	Range points of terrain profile	terx()	N/A
$tery$	Height points of terrain profile	tery()	N/A
th_{max}	Visible portion of maximum PE calculation angle	thmax	INPUTVAR
t_{loss}	Troposcatter loss in dB	tloss	N/A
$tlst$	Troposcatter loss term	tlst	N/A
$tlst_s$	Troposcatter loss term for smooth surface case	tlsts	N/A
$tlst_{wr}$	Troposcatter loss term used in TROPOSCAT SU	tsltwr	APM_VAR
T_{ropo}	Troposcatter calculation flag: '.false.'= no troposcatter calcs '.true.' = troposcatter calcs	tropo	INPUTVAR
$twoka$	Twice the effective earth's radius	twoka	APM_VAR
$twoka_{down}$	Twice the effective earth radius for downward path	twoka_down	APM_VAR
tx	Range points of terrain profile	tx()	N/A
ty	Adjusted height points of terrain profile	ty()	N/A
tyh	Adjusted height points of sampled terrain profile at every PE range step	tyh()	N/A
U	Complex field at current PE range r	u()	N/A
$Udum$	Dummy array used for temporary storage of real or imaginary part of complex PE field array U	udum()	N/A
$Ulast$	Complex field at previous PE range r_{last}	ulst()	N/A
w	Difference equation of complex PE field	w()	N/A
$wind$	Array of wind speeds	wind()	N/A
$wind_{dir}$	Angle between antenna boresight and upwind direction	wind_dir	REFRACTIVITY
x	Current output range	x	N/A
x	Field array to be transformed - dimensioned $2^{n_{fft}}$ in calling SU	x()	N/A
$xdum$	Real part of complex field array	xdum()	N/A
xo_{con}	Constant used in determining ϑ_{out}	xocon	APM_VAR
xp	Real part of spectral field	xp()	N/A
x_r	Terminal range - called x_{ROn} in ROCALC SU	rout	N/A
$x_{reflect}$	Range at which ray is reflected	xreflect	N/A
x_{ROn}	Next range in RO region	xROn	APM_VAR
x_{ROp}	Previous range in RO region	xROp	APM_VAR
x_{temp}	Temporary range in ray trace step	xtemp	N/A
x_{sum}	Running sum of range during ray trace	xsum	N/A
xx	Fractional range for interpolation	xx	N/A

Table 139. Variable name cross reference. (continued)

SDD variable name	Description	FORTRAN source code name	FORTRAN common block name
y_{ch}	Height of terrain at the current PE range relative to hm_{ref}	ych	N/A
y_{cur}	Height of ground at current range r	ycur	APM_VAR
y_{curm}	Height of ground midway between last and current PE range	ycurm	APM_VAR
y_{diff}	y_{cur} - y_{last}	ydiff	N/A
$ydum$	Imaginary part of complex field array	ydum()	N/A
y_{fref}	Ground elevation height at source	yfref	APM_VAR
y_{last}	Height of ground at previous range r_{last}	ylast	APM_VAR
y_{lh}	Height of terrain at the previous PE range relative to hm_{ref}	ylh	N/A
ym	Particular solution of difference equation	ym()	N/A
yp	Imaginary part of spectral field	yp()	N/A
y_{ref}	Ground elevation height at current range	yref	N/A
z_c	Height at which to compute propagation factor for clutter calculations relative to hm_{ref}	zc	APM_VAR
z_d	Terminal height of direct ray	zd	N/A
z_{int}	Interpolated terrain elevation at current output range	zint	N/A
z_k	Height of k^{th} RO index	zk	N/A
z_{lim}	Height limit for PE calculation region	zlim	APM_VAR
z_{limt}	ht_{lim}-10^{-5}	zlimt	N/A
z_{max}	Total height of the FFT/PE calculation domain	zmax	APM_VAR
$zout$	Array containing all desired output heights referenced to h_{minter}	zout()	N/A
$zoutma$	Array output heights relative to “real” ant_{ref}	zoutma()	N/A
$zoutpa$	Array output heights relative to “image” ant_{ref}	zoutpa()	N/A
$zout\_rtg$	Dynamically allocated array of receiver heights specified relative to the local ground height.	zout_rtg()	INPUTVAR
z_r	Receiver height	height, zr	N/A
zro	Array of output heights in RO region	zro()	N/A
zrt	Intermediate height array, RO region	zrt()	N/A
z_{test}	Height in PE region that must be reached for hybrid model	ztest	N/A
z_{tol}	Height tolerance for Newton's method	ztol	APM_VAR
zxo	Height of the ground at the current output range step	zxo()	N/A

SOFTWARE TEST DESCRIPTION

FOR THE

ADVANCED PROPAGATION MODEL CSCI
(Version 2.1.04)

20 December 2006

CONTENTS

TABLES

1. SCOPE

1.1 IDENTIFICATION

Advanced Propagation Model (APM) Version 2.1.04 computer software configuration item (CSCI). The purpose of the APM CSCI is to calculate range-dependent electromagnetic (EM) system propagation loss and propagation factor within a heterogeneous atmospheric medium over variable terrain, where the radio-frequency index of refraction is allowed to vary both vertically and horizontally. Numerous external applications require EM-system propagation loss values. The APM model described by this document may be applied to two such external applications, one which displays propagation loss on a range versus height scale (commonly referred to as a coverage diagram) and one which displays propagation loss on a propagation loss versus range/height scale (commonly referred to as a loss diagram).

1.2 DOCUMENT OVERVIEW

This document specifies the test cases and test procedures necessary to perform qualification testing of the APM CSCI. A discussion of precise input values of each input variable required to perform the test together with final expected test results is presented.

2. REFERENCE DOCUMENTS

1. Commander-In-Chief, Pacific Fleet Meteorological Requirement (PAC MET) 87-04, “Range Dependent Electromagnetic Propagation Models.”

2. Naval Oceanographic Office, “Software Documentation Standards and Coding Requirements for Environmental System Product Development,” April 1990.

3. Space and Naval Warfare Systems Center San Diego (SSC SD), “Software Requirements Specification for the Advanced Propagation Model (APM) CSCI (Version 1.3.1),” Aug. 1998.

4. Space and Naval Warfare Systems Center San Diego (SSC SD), “Software Design Document for the Advanced Propagation Model (APM) CSCI (Version 1.3.1),” Aug. 1998.

5. Space and Naval Warfare Systems Center San Diego (SSC SD), “Software Design Document for the Advanced Propagation Model (APM) CSCI,” TD 3033, Aug. 1998.

3. TEST PREPARATIONS

3.1 HARDWARE PREPARATION

Not applicable

3.2 SOFTWARE PREPARATION

A short driver program, APMMAIN.F90, is provided in Section 7. This program exercises the main software components, APMINIT CSC, APMSTEP CSC, XOINIT CSC, and XOSTEP CSC that comprise the APM CSCI. The driver program demonstrates how to access the APM CSCI and to exercise the test cases listed in the following sections. It is written to read all necessary input data for the test cases from files in a specific format. All necessary input information is presented in tables in Section 4.3 and the input files for each test case are listed in Section 8.

One of the main features of APM is the use of dynamic allocation in most of the arrays used for numeric calculations and as inputs to the model. The external CSCI application designer must be careful to properly allocate memory and initialize all variable and array inputs to APM. Ultimately, it is the responsibility of the external CSCI application designer to provide the necessary input in the form required by the APM CSCI.

3.3 OTHER PRETEST PREPARATION

None.

4. TEST DESCRIPTIONS

The test specification for the APM CSCI consists of 48 separate tests that exercise all subroutines and functions of the CSCI. For ease of testing, each of these 48 tests is given a name describing which portion of the APM CSCI is being exercised. All 48 tests and their descriptions are listed in Table 1.

Table 1. Test Names and Descriptions.

Test Name	Description
ABSORB	Gaseous absorption attenuation rate is specified.
AFEVAP	Enables the computation of propagation angles and factors for an evaporation duct environment.
AFSBD	Enables the computation of propagation angles and factors for a surface-based duct environment.
AFSTD	Enables the computation of propagation angles and factors for a standard atmosphere.
AIRBORNE	Airborne platform for antenna height.
BLOCK	The terrain profile consists of a vertical flat-topped block or obstacle in which the terrain slope is undefined.
CLEVAPW	Computes clutter-to-noise ratio for an evaporation duct environment where the propagation path is entirely over water.
CLSBDL	Computes clutter-to-noise ratio for a surface-based duct environment where the propagation path is entirely over land.
CLSBDW	Computes clutter-to-noise ratio for a surface-based duct environment where the propagation path is entirely over water.
CLSBDWL	Computes clutter-to-noise ratio for a surface-based duct environment where the propagation path is a mixed land-sea path.
COSEC2	Antenna pattern is of cosecant-squared type.
EDUCT	The refractivity consists of a 14 meter evaporation duct profile.
EDUCTRF	The refractivity consists of a 14 meter evaporation duct in the presence of rough seas with wind speed of 10 m/s.
FLTA50	Raised flat land with antenna height of 50 m.
GASABS	The surface absolute humidity and surface air temperature are specified in order to compute a gaseous absorption attenuation rate.
GAUSS	Antenna pattern is of Gaussian type.
HEIGHT_RTG	Computes the propagation loss/factor for specific heights relative to the local ground height.
HF10TER	HF (10 MHz) emitter where the propagation path is entirely over land.
HF20QWVD	HF (20 MHz) emitter with quarter-wave dipole antenna; propagation path is entirely over water.
HF20RF	HF (20 MHz) emitter with quarter-wave dipole antenna; propagation path is over a rough sea surface with a wind speed of 10 m/s.
HF30	HF (30 MHz) emitter over a smooth sea surface.
HIBW	Large vertical beamwidth is specified.
HIEL	High elevation angle is specified.
HIFREQ	High frequency.
HITRAN	High transmitter antenna height.
HORZ	Horizontal polarization antenna and standard atmosphere.
HTFIND	Antenna pattern is of generic height-finder type.
LOBW	Small vertical beamwidth is specified.
LOEL	Low elevation angle is specified.

Table 1. Test Names and Descriptions. (Continued)

Test Name	Description
LOFREQ	Low frequency.
LOTRAN	Low transmitter antenna height.
MPRT	Mid-path reflection over wedge.
PERW	Propagation over rounded wedge using PE model only.
PVT	Parabolic valley with short range.
RDLONGB	Range-dependent refractivity over a DTED-extracted terrain profile from Long Beach to Point Mugu, using vertical polarization and generic ground composition types.
RNGDEP	Range-dependent refractivity over smooth earth (over-water case).
SBDUCT	300 meter surface-based duct, over-water case.
SBDUCTRF	Exercises rough surface model for surface-based duct case, with wind speed of 10 m/s.
SINEX	Antenna pattern is of Sine(X)/X type.
TROPOS	Exercises troposcatter model for smooth surface (over-water case).
TROPOT	Exercises troposcatter model for terrain case.
USERDEFA	User-defined antenna pattern with explicit power and angle information.
USERHF	Antenna pattern is of specific height finder type, with user-specified cut-back angles and power factors.
VERT	Vertical polarization antenna is specified (short range over-water case, standard atmosphere).
VERTMIX	Vertical polarization antenna over mixed land-sea terrain path.
VERTSEA	Vertical polarization antenna is specified (long range over-water case, ducting atmosphere).
VERTUSRD	Vertical polarization antenna and user-specified dielectric ground constants.
WEDGE	The terrain profile consists of a triangular wedge.

4.1 REQUIREMENTS ADDRESSED

Not applicable.

4.2 PREREQUISITE CONDITIONS

None.

4.3 TEST INPUTS

Although there are actual values for all input parameters listed in the input files in Section 8, some are ignored depending on the values of certain input parameters. Those input parameters that are inapplicable depending on the test case, are listed as “N/A” in the tables. Note that for all test cases, the error flags *lerr6* and *lerr12* are set to

".TRUE.". These flags allow for extra error control regarding terrain and refractivity inputs. We recommend that these error flags always be set to ".TRUE.". However, we allowed the capability of the external applications designer to bypass these error controls according to the application.

The external environmental data element requirements are listed in Table 2 for each test name, with Table 3 through Table 9 providing specific height and M-unit values. The external EM system data element requirements are listed Table 11.

Table 2. External environmental data element requirements[a].

Test Name	*hmsl; refmsl* Table	n_{prof}	*lvlp*	*rngprof* [b] Table	abs_{hum} (g/m^3)	t_{air} (°C)	γ_a (dB/km)	n_w	*rngwind* (km)	*wind* (m/s)	$wind_{dir}$ (deg)
ABSORB	3	1	2	0.	0.	0.	.146	0	N/A	N/A	0.
AFEVAP	6	1	17	0.	0.	0.	0.	0	N/A	N/A	0.
AFSBD	4	1	4	0.	0.	0.	0.	0	N/A	N/A	0.
AFSTD	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
AIRBORNE	9	1	5	0.	0.	0.	0.	0	N/A	N/A	0.
BLOCK	3	1	2	0.	7.5	0.	0.	0	N/A	N/A	0.
CLEVAPW	10	1	50	0.	0.	0.	0.	1	0.	10.	0.
CLSBDL	4	1	4	0.	0.	0.	0.	0	N/A	N/A	0.
CLSBDW	4	1	4	0.	0.	0.	0.	1	0.	10.	0.
CLSBDWL	4	1	4	0.	0.	0.	0.	1	0.	10.	45.
COSEC2	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
EDUCT	5	1	21	0.	0.	0.	0.	0	N/A	N/A	0.
EDUCTRF	5	1	21	0.	0.	0.	0.	1	0.	10.	0.
FLTA50	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
GASABS	3	1	2	0.	10.	25.	0.	0	N/A	N/A	0.
GAUSS	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
HEIGHT_RTG	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
HF10TER	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
HF20QWVD	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
HF20RF	3	1	2	0.	0.	0.	0.	1	0.	10.	0.
HF30	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
HIBW	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
HIEL	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
HIFREQ	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
HITRAN	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
HORZ	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.

Table 2. External environmental data element requirements[a]. (Continued)

Test Name	*hmsl; refmsl* Table	n_{prof}	*lvlp*	*rngprof* [b] Table	abs_{hum} (g/m^3)	t_{air} (°C)	γ_a (dB/km)	n_w	*rngwind* (km)	*wind* (m/s)	$wind_{dir}$ (deg)
HTFIND	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
LOBW	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
LOEL	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
LOFREQ	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
LOTRAN	3	1	2	0.	0.	0.	0.	0	N/A	N/A	0.
MPRT	3	1	2	0.	7.5	0.	0.	0	N/A	N/A	0.
PERW	3	1	2	0.	7.5	0.	0.	0	N/A	N/A	0.
PVT	3	1	2	0.	7.5	0.	0.	0	N/A	N/A	0.
RDLONGB	7	2	4	7	0.	0.	0.	0.	N/A	N/A	0.
RNGDEP	8	2	4	8	0.	0.	0.	0.	N/A	N/A	0.
SBDUCT	4	1	4	0.	0.	0.	0.	0.	N/A	N/A	0.
SBDUCTRF	4	1	4	0.	0.	0.	0.	1.	0.	10.	0.
SINEX	3	1	2	0.	0.	0.	0.	0.	N/A	N/A	0.
TROPOS	3	1	2	0.	0.	0.	0.	0.	N/A	N/A	0.
TROPOT	3	1	2	0.	0.	0.	0.	0.	N/A	N/A	0.
USERDEFA	4	1	4	0.	0.	0.	0.	0.	N/A	N/A	0.
USERHF	3	1	2	0.	0.	0.	0.	0.	N/A	N/A	0.
VERT	3	1	2	0.	0.	0.	0.	0.	N/A	N/A	0.
VERTMIX	3	1	2	0.	0.	0.	0.	0.	N/A	N/A	0.
VERTSEA	4	1	4	0.	0.	0.	0.	0.	N/A	N/A	0.
VERTUSRD	3	1	2	0.	0.	0.	0.	0.	N/A	N/A	0.
WEDGE	3	1	2	0.	0.	0.	0.	0.	N/A	N/A	

[a]The interpolation flag, iextra, is set to 0 for all test cases.
[b]The refractivity profile range is in meters except for cases RDLONGB and RNGDEP, which refer to the specific Table number.

Table 3.Standard atmosphere with 118 M/km gradient.

i	$hmsl_{i,1}$ (meters)	$refmsl_{i,1}$ (M-unit)
1	0.	350.
2	1000.	468.

Table 4. 300 meter surface based duct atmosphere.

i	$hmsl_{i,1}$ (meters)	$refmsl_{i,1}$ (M-unit)
1	0.	339.0
2	250.	368.5
3	300.	319.0
4	1500.	460.6

Table 5. Atmosphere for 14 meter evaporation duct.

i	$hmsl_{i,1}$ (meters)	$refmsl_{i,1}$ (M-unit)
1	0.000	339.00
2	0.040	335.10
3	0.100	333.66
4	0.200	332.60
5	0.398	331.54
6	0.794	330.51
7	1.585	329.53
8	4.362	328.65
9	6.310	327.96
10	12.589	327.68
11	14.000	327.67
12	25.119	328.13
13	39.811	329.25
14	50.119	330.18
15	63.096	331.44
16	79.433	334.32
17	100.000	335.33
18	125.893	338.20
19	158.489	341.92
20	199.526	346.69
21	209.526	347.87

Table 6. Atmosphere for 24 meter evaporation duct.

i	$hmsl_{i,1}$ (meters)	$refmsl_{i,1}$ (M-unit)
1	0.0	0.0
2	0.135	-20.40
3	0.223	-21.89
4	0.368	-23.37
5	0.607	-24.84
6	1.000	-26.29
7	1.649	-27.71
8	2.718	-29.08
9	4.482	-30.35
10	7.389	-31.49
11	12.182	-32.39
12	20.086	-32.90
13	24.000	-32.95
14	33.115	-32.78
15	54.598	-31.59
16	90.017	-28.66
17	148.413	-22.86

Table 7. Range-dependent atmosphere, standard atmosphere to surface-based duct.

	Standard Atmosphere $rngprof_1$ = 0 km		Surface-based Duct $rngprof_2$ = 100 km	
i	$hmsl_{i,1}$ (meters)	$refmsl_{i,1}$ (M-unit)	$hmsl_{i,2}$ (meters)	$refmsl_{i,2}$ (M-unit)
1	0.	350.	0.	339.0
2	0.	350.	250.	368.5
3	0.	350.	300.	319.0
4	1000.	468.	1000.	401.6

Table 8. Range-dependent atmosphere, surface-based duct to high elevated duct.

	Surface-based Duct $rngprof_1$ = 0. km		High Elevated Duct $rngprof_2$ = 250. km	
i	$hmsl_{i,1}$ meters	$refmsl_{i,1}$ M-unit	$hmsl_{i,2}$ meters	$refmsl_{i,2}$ M-unit
1	0.	330.	0.	330.
2	100.	342.5	600.	405.
3	230.	312.5	730.	375.
4	2000.	517.8	2000.	522.3

Table 9. Elevated duct.

i	$hmsl_{i,1}$ (meters)	$refmsl_{i,1}$ (M-unit)
1	0.	209.2
2	1100.	339.0
3	1500.	386.2
4	1625.	361.5
5	5625.	833.5

Table 10. Atmosphere for 20 meter evaporation duct.

i	$hmsl_{i,1}$ (meters)	$refmsl_{i,1}$ (M-unit)
1	0.000000	339.000000
2	0.833333	318.405284
3	1.666667	316.841934
4	2.500000	315.968883
5	3.333333	315.378476
6	4.166667	314.942950
7	5.000000	314.605389
8	5.833333	314.335435
9	6.666667	314.114965
10	7.500000	313.932289
11	8.333333	313.779427
12	9.166667	313.650685
13	10.000000	313.541859
14	10.833333	313.449758
15	11.666667	313.371900
16	12.500000	313.306318
17	13.333333	313.251426
18	14.166667	313.205927
19	15.000000	313.168748
20	15.833333	313.138987
21	16.666667	313.115883
22	17.500000	313.098787
23	18.333333	313.087139
24	19.166667	313.080455
25	20.000000	313.078311
26	20.833333	313.080339
27	21.666667	313.086209
28	22.500000	313.095632
29	23.333333	313.108350

Table 10. Atmosphere for 20 meter evaporation duct (continued).

i	$hmsl_{i,1}$ (meters)	$refmsl_{i,1}$ (M-unit)
30	24.166667	313.124130
31	25.000000	313.142767
32	25.833333	313.164071
33	26.666667	313.187874
34	27.500000	313.214022
35	28.333333	313.242374
36	29.166667	313.272804
37	30.000000	313.305194
38	30.833333	313.339436
39	31.666667	313.375432
40	32.500000	313.413091
41	33.333333	313.452328
42	34.166667	313.493066
43	35.000000	313.535231
44	35.833333	313.578758
45	36.666667	313.623583
46	37.500000	313.669648
47	38.333333	313.716898
48	39.166667	313.765283
49	40.000000	313.814755
50	1200.000000	444.851829

Table 11. External EM system data element requirements.

Test Name	f_{MHz} (MHz)	ant_{ht} (meters)	i_{pat} [a]	i_{pol} [b]	μ_{bw} (deg)	μ_{o} (deg)	C_{lut}	ant_{gain} (dBi)	θ_{hbw} (deg)	τ (μsec)	N_f (dB)	L_{sys} (dB)	P_t (kW)
ABSORB	20000.	25.	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
AFEVAP	3000	25	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
AFSBD	3000	25	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
AFSTD	1000	25	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
AIRBORNE	900.	2500.	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
BLOCK	1000.	101.	1	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
CLEVAPW	10,000.	25.	3	1	2	0.	.true.	32.	1.5	1.3	10.0	8.4	285.
CLSBDL	3000.	15.	5	0	1.5	0.5	.true.	39.	2.0	9.0	5.5	3.0	2000.
CLSBDW	3000.	15.	5	0	1.5	0.5	.true.	39.	2.0	9.0	5.5	3.0	2000.
CLSBDWL	5600.	15.	3	0	16.	0.	.true.	30.	1.5	1.3	5.0	3.0	230.
COSEC2	1000.	25.	4	0	1.	0.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
EDUCT	10,000.	15.	2	0	5.	0.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
EDUCTRF	10,000.	15.	2	0	5.	0.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
FLTA50	1000.	50.	1	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
GASABS	20,000.	25.	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
GAUSS	1000.	25.	2	0	1.	0.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
HEIGHT_RTG	162.4	54.864	1	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
HF10TER	10.	20.	1	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
HF20QWVD	20.	20.	8	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
HF20RF	20.	20.	8	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
HF30	30.	10.	1	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
HIBW	1000.	25.	3	0	45.	0.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
HIEL	1000.	25.	2	0	1.	10.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
HIFREQ	20,000.	25.	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
HITRAN	1000.	100.	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
HORZ	1000.	25.	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
HTFIND	1000.	25.	5	0	2.	0.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
LOBW	1000.	25.	2	0	0.5	0.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
LOEL	1000.	25.	2	0	1.	-10.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
LOFREQ	100.	25.	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
LOTRAN	1000.	1.5	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A

Table 11. External EM system data element requirements (continued).

Test Name	f_{MHz} (MHz)	ant_{ht} (meters)	i_{pat} [a]	i_{pol} [b]	μ_{bw} (deg)	μ_o (deg)	C_{lut}	ant_{gain} (dBi)	θ_{hbw} (deg)	τ (μsec)	N_f (dB)	L_{sys} (dB)	P_t (kW)
MPRT	300.	800.	2	1	0.5	-2.5	.false.	N/A	N/A	N/A	N/A	N/A	N/A
PERW	300	10.	1	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
PVT	500.	10.	1	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
RDLONGB	150.	100.	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
RNGDEP	3000.	25.	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
SBDUCT	3000.	25.	2	0	5.	0.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
SBDUCTRF	3000.	25.	2	1	5.	0.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
SINEX	1000.	25.	3	0	1.	0.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
TROPOS	100.	25.	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
TROPOT	100.	25.	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
USERDEFA[c]	900.	6.	7	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
USERHF[d]	1000.	25.	6	0	1.	0.	.false.	N/A	N/A	N/A	N/A	N/A	N/A
VERT	1000.	25.	1	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
VERTMIX	100.	10.	1	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
VERTSEA	100.	25.	1	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
VERTUSRD	100.	10.	1	1	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A
WEDGE	1000.	25.	1	0	N/A	N/A	.false.	N/A	N/A	N/A	N/A	N/A	N/A

[a]Antenna Pattern:1=Omni-directional; 2=Gaussian; 3=Sine(X)/X; 4=Cosecant-squared; 5=Generic height-finder; 6=User-specified height finder, 7=User-defined; 8=Quarter-wave dipole antenna pattern.

[b]Polarization: 0=Horizontal; 1=Vertical

[c]See Table 12 for *hffang* and *hffac* parameters (n_{facs}=54)..

[d]See Table 13 for *hffang* and *hffac* parameters (n_{facs}=10).

Table 12. Height finder angles and factors for case USERDEFA.

i	$hfang_i$ (deg)	$hffac_i$
1	-17	.017
2	-16	.044
3	-15	.080
4	-14	.126
5	-13	.182
6	-12	.245
7	-11	.316
8	-10	.389
9	-9	.479
10	-8	.556
11	-7	.631
12	-6	.716
13	-5	.785
14	-4	.861
15	-3	.912
16	-2	.966
17	-1	.998
18	0	1.00
19	1	1.00
20	2	.966
21	3	.902
22	4	.822
23	5	.742
24	6	.646
25	7	.569
26	8	.501
27	9	.452
28	10	.422
29	11	.402
30	12	.389
31	13	.375
32	14	.359
33	15	.339
34	16	.305
35	17	.276
36	18	.245
37	19	.221
38	20	.210
39	21	.199
40	22	.190
41	23	.180

Table 12. Antenna pattern angles and factors for case USERDEFA (continued).

i	$hfang_i$ (deg)	$hffac_i$
42	24	.164
43	25	.148
44	26	.130
45	27	.110
46	28	.095
47	29	.077
48	30	.070
49	31	.065
50	32	.058
51	33	.050
52	34	.039
53	35	.031
54	36	.025

Table 13. Height finder angles and factors for case USERHF.

i	$hfang_i$ (deg)	$hffac_i$
1	1.0	0.9
2	1.5	0.8
3	2.0	0.7
4	2.5	0.6
5	3.0	0.5
6	3.5	0.4
7	4.0	0.3
8	4.5	0.2
9	5.0	0.1
10	5.5	0.0

The external implementation data element requirements that must be specified for each test are listed in Table 14. For all cases except those noted, T_{ropo} is '.true.', and h_{min} is 0.0 meters. Note: the *lang* flag should only be used for over-water propagation paths and should not be enabled for cases where any portion of the path is over land.

Table 14. External implementation data element requirements.

Test Name	h_{max} (meters)	n_{rout}	n_{zout}	PE_{flag}	r_{max} (km)	r_{mult}	th_{max} (deg)	*lerr6*	*lerr12*	*lang*
ABSORB	200.	1	20	.false.	50.	N/A	N/A	.true	.true.	.false.
AFEVAP	1000.	1	20	.false.	50.	N/A	N/A	.true	.true.	.true.
AFSBD	3000.	1	20	.false.	100.	N/A	N/A	.true	.true.	.true.
AFSTD	1000.	1	20	.false.	50.	N/A	N/A	.true	.true.	.true.
AIRBORNE	5000.	1	20	.false.	250.	N/A	N/A	.true	.true.	.false.
BLOCK	400.	1	20	.false.	60.	N/A	N/A	.true	.true.	.false.
CLEVAPW	1000.	100	2	.false.	100.	N/A	N/A	.false.	.true.	.false.
CLSBDL	1000.	100	2	.false.	100.	N/A	N/A	.false.	.true.	.false.
CLSBDW	1000.	100	2	.false.	100.	N/A	N/A	.false.	.true.	.false.
CLSBDWL	3000.	100	2	.false.	200.	N/A	N/A	.false.	.true.	.false.
COSEC2	2000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
EDUCT	200.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
EDUCTRF	200.	1	20	.false.	100.	N/A	N/A	.true.	.true.	.false.
FLTA50	100.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
GASABS	200.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
GAUSS	2000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
HEIGHT_RTG[a]	500.	20	1	.false.	18.41	N/A	N/A	.false.	.true.	.false.
HF10TER	2000.	30	2	.false.	249.	N/A	N/A	.true.	.true.	.false.
HF20QWVD	1000.	1	20	.false.	100.	N/A	N/A	.true.	.true.	.false.
HF20RF	1000.	1	20	.false.	100.	N/A	N/A	.true.	.true.	.false.
HF30	1000.	1	20	.false.	100.	N/A	N/A	.true.	.true.	.false.
HIBW	2000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
HIEL	20,000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
HIFREQ	200.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
HITRAN	1000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
HORZ	2000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
HTFIND	2000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
LOBW	2000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
LOEL	20,000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
LOFREQ	5000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
LOTRAN	10,000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
MPRT	1100.	30	1	.false.	60.	N/A	N/A	.true.	.true.	.false.
PERW	1000.	20	1	.true.	50.	1.	10.	.true.	.true.	.false.
PVT	2000.	1	20	.false.	10.	N/A	N/A	.true.	.true.	.false.
RDLONGB	1000.	1	20	.false.	100.	N/A	N/A	.true.	.true.	.false.
RNGDEP	2000.	1	20	.false.	250.	N/A	N/A	.true.	.true.	.false.
SBDUCT	5000.	1	20	.false.	200.	N/A	N/A	.true.	.true.	.false.
SBDUCTRF	1000.	1	20	.false.	200.	N/A	N/A	.true.	.true.	.false.

Table 14. External implementation data element requirements (continued).

Test Name	h_{max} (meters)	n_{rout}	n_{zout}	PE_{flag}	r_{max} (km)	r_{mult}	th_{max} (deg)	*lerr6*	*lerr12*	*lang*
SINEX	2000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
TROPOS[b]	2000.	1	20	.false.	200.	N/A	N/A	.true.	.true.	.false.
TROPOT[b]	2000.	1	20	.false.	200.	N/A	N/A	.true.	.true.	.false.
USERDEFA	3000.	1	20	.false.	300.	N/A	N/A	.true.	.true.	.false.
USERHF	2000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
VERT	2000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
VERTMIX	1000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
VERTSEA	1000.	1	20	.false.	300.	N/A	N/A	.true.	.true.	.false.
VERTUSRD	1000.	1	20	.false.	50.	N/A	N/A	.true.	.true.	.false.
WEDGE	1000.	1	20	.false.	100.	N/A	N/A	.true.	.true.	.false.

[a] n_{zout_rtg}.= 3; see Table 15 for specific heights.
[b] T_{ropo} = '.true.'

Table 15. Heights relative to ground for test case HEIGHT_RTG.

i	$zout\_rtg_i$ (meters)
1	1.2
2	2.5
3	5.1

The external terrain data element requirements are only applicable to select test cases and are listed below in Table 16. All test cases where no terrain profile is specified implies the propagation path is entirely over sea water. Terrain profiles used for these specific test cases are listed in Table 17 through Table 32.

Table 16. External terrain data element requirements.

Test Name	*terx, tery* Table	i_{tp}	i_{gr}	*igrnd*	*rgrnd* (km)	*dielec* (ε_r, σ)[a]	i_{gc}	γc (dB)	γrng (km)
BLOCK	Table 17	6	1	7	0.	(7.5, .01)	N/A	N/A	N/A
CLSBDL	Table 18	374	2	Table 19	Table 19	N/A	2	Table 19	Table 19
CLSBDWL	Table 20	265	2	Table 21	Table 21	N/A	2	Table 21	Table 21
FLTA50	Table 22	2	1	7	0.	(7.0, .01)	N/A	N/A	N/A
HEIGHT_RTG	Table 23	304	1	3	0.	N/A	N/A	N/A	N/A
HF10TER	Table 20	265	2	Table 24	Table 24	Table 24	N/A	N/A	N/A
MPRT	Table 25	5	1	7	0.	(7.5, 0.01)	N/A	N/A	N/A
PERW	Table 26	11	1	7	0.	(7.5, 0.01)	N/A	N/A	N/A
PVT	Table 27	17	1	7	0.	(7.5, 0.01)	N/A	N/A	N/A
RDLONGB	Table 28	167	6	Table 29	Table 29	N/A	N/A	N/A	N/A
TROPOT	Table 28	167	6	Table 29	Table 29	N/A	N/A	N/A	N/A
VERTMIX	Table 30	2	2	Table 30	Table 30	N/A	N/A	N/A	N/A
VERTUSRD	Table 31	2	1	7	0.	(3., 6e-4)	N/A	N/A	N/A
WEDGE	Table 32	5	1	0	0.	N/A	N/A	N/A	N/A

[a] ε_r = relative permittivity; σ = conductivity (S/m)

Table 17 Terrain profile for test case BLOCK.

i	$terx_i$ (km)	$tery_i$ (meters)
1	0.	1.
2	10.	1.
3	10.	200.
4	40.	200.
5	40.	1
6	60.	1

Table 18. Terrain profile for test case CLSBDL

i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)
1	0.00	91.0	43	10.50	37.9	85	21.00	10.8
2	0.25	81.9	44	10.75	36.7	86	21.25	11.4
3	0.50	66.5	45	11.00	36.8	87	21.50	11.7
4	0.75	53.6	46	11.25	34.9	88	21.75	10.6
5	1.00	42.3	47	11.50	31.7	89	22.00	8.5
6	1.25	40.6	48	11.75	32.5	90	22.25	8.0
7	1.50	44.8	49	12.00	35.8	91	22.50	8.7
8	1.75	53.4	50	12.25	32.7	92	22.75	9.0
9	2.00	64.4	51	12.50	25.6	93	23.00	9.1
10	2.25	62.8	52	12.75	22.9	94	23.25	8.7
11	2.50	53.6	53	13.00	22.9	95	23.50	7.9
12	2.75	54.9	54	13.25	22.9	96	23.75	6.7
13	3.00	62.6	55	13.50	22.9	97	24.00	5.1
14	3.25	63.2	56	13.75	22.7	98	24.25	5.2
15	3.50	59.4	57	14.00	22.4	99	24.50	6.3
16	3.75	57.1	58	14.25	22.3	100	24.75	7.0
17	4.00	55.7	59	14.50	22.4	101	25.00	7.4
18	4.25	53.2	60	14.75	22.4	102	25.25	7.6
19	4.50	49.8	61	15.00	22.5	103	25.50	7.6
20	4.75	43.7	62	15.25	20.3	104	25.75	9.9
21	5.00	36.0	63	15.50	16.7	105	26.00	13.8
22	5.25	31.5	64	15.75	15.2	106	26.25	15.2
23	5.50	28.9	65	16.00	15.2	107	26.50	15.2
24	5.75	24.0	66	16.25	15.2	108	26.75	15.2
25	6.00	17.7	67	16.50	15.2	109	27.00	15.2
26	6.25	15.2	68	16.75	15.3	110	27.25	15.2
27	6.50	15.2	69	17.00	15.3	111	27.50	15.2
28	6.75	15.2	70	17.25	15.3	112	27.75	17.6
29	7.00	15.2	71	17.50	15.3	113	28.00	21.4
30	7.25	17.6	72	17.75	15.2	114	28.25	22.9
31	7.50	21.4	73	18.00	15.2	115	28.50	22.9
32	7.75	24.6	74	18.25	15.2	116	28.75	23.7
33	8.00	27.4	75	18.50	15.2	117	29.00	25.1
34	8.25	30.3	76	18.75	15.2	118	29.25	25.7
35	8.50	33.3	77	19.00	15.2	119	29.50	25.8
36	8.75	33.2	78	19.25	15.2	120	29.75	24.0
37	9.00	31.3	79	19.50	15.2	121	30.00	21.0
38	9.25	30.0	80	19.75	13.1	122	30.25	19.8
39	9.50	29.2	81	20.00	9.7	123	30.50	19.7
40	9.75	33.1	82	20.25	8.4	124	30.75	18.3
41	10.00	40.1	83	20.50	8.5	125	31.00	16.1

Table 18. Terrain profile for test case CLSBDL (continued).

i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)
127	31.50	12.5	169	42.00	50.3	211	52.50	24.5
128	31.75	14.1	170	42.25	51.6	212	52.75	24.7
129	32.00	17.9	171	42.50	51.6	213	53.00	24.8
130	32.25	19.3	172	42.75	51.7	214	53.25	27.5
131	32.50	19.3	173	43.00	51.7	215	53.50	31.9
132	32.75	15.7	174	43.25	50.0	216	53.75	33.8
133	33.00	9.9	175	43.50	46.9	217	54.00	34.0
134	33.25	6.4	176	43.75	48.0	218	54.25	34.0
135	33.50	4.4	177	44.00	51.8	219	54.50	33.7
136	33.75	4.2	178	44.25	53.3	220	54.75	35.6
137	34.00	5.2	179	44.50	53.3	221	55.00	39.0
138	34.25	7.3	180	44.75	53.0	222	55.25	43.6
139	34.50	10.1	181	45.00	52.4	223	55.50	48.8
140	34.75	11.1	182	45.25	50.3	224	55.75	57.6
141	35.00	11.1	183	45.50	47.0	225	56.00	68.9
142	35.25	11.0	184	45.75	43.7	226	56.25	76.5
143	35.50	11.0	185	46.00	40.4	227	56.50	81.7
144	35.75	9.9	186	46.25	38.6	228	56.75	82.0
145	36.00	8.3	187	46.50	37.9	229	57.00	78.8
146	36.25	7.1	188	46.75	33.2	230	57.25	77.9
147	36.50	6.3	189	47.00	25.8	231	57.50	78.5
148	36.75	7.9	190	47.25	22.7	232	57.75	77.4
149	37.00	11.0	191	47.50	22.4	233	58.00	75.2
150	37.25	14.6	192	47.75	20.2	234	58.25	77.8
151	37.50	18.5	193	48.00	16.7	235	58.50	83.4
152	37.75	22.3	194	48.25	15.2	236	58.75	87.8
153	38.00	26.2	195	48.50	15.2	237	59.00	91.4
154	38.25	30.1	196	48.75	15.2	238	59.25	94.0
155	38.50	33.9	197	49.00	15.2	239	59.50	96.1
156	38.75	34.7	198	49.25	15.2	240	59.75	92.3
157	39.00	33.5	199	49.50	15.2	241	60.00	84.7
158	39.25	29.3	200	49.75	17.5	242	60.25	83.6
159	39.50	23.0	201	50.00	21.3	243	60.50	87.1
160	39.75	19.6	202	50.25	25.1	244	60.75	91.0
161	40.00	18.1	203	50.50	29.0	245	61.00	95.0
162	40.25	19.1	204	50.75	32.8	246	61.25	98.8
163	40.50	21.8	205	51.00	36.6	247	61.50	102.5
164	40.75	25.8	206	51.25	38.1	248	61.75	104.8
165	41.00	30.6	207	51.50	38.1	249	62.00	106.1
166	41.25	36.5	208	51.75	33.9	250	62.25	109.6
167	41.50	43.1	209	52.00	27.0	251	62.50	114.3
168	41.75	47.4	210	52.25	24.3	252	62.75	117.0

Table 18. Terrain profile for test case CLSBDL (continued).

i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)
253	63.00	118.4	295	73.50	79.9	337	84.00	56.7
254	63.25	119.8	296	73.75	78.0	338	84.25	51.5
255	63.50	121.3	297	74.00	76.0	339	84.50	48.1
256	63.75	119.2	298	74.25	71.5	340	84.75	46.5
257	64.00	114.8	299	74.50	65.1	341	85.00	46.0
258	64.25	111.2	300	74.75	60.9	342	85.25	45.7
259	64.50	108.0	301	75.00	58.2	343	85.50	45.7
260	64.75	107.7	302	75.25	53.8	344	85.75	47.8
261	65.00	109.4	303	75.50	48.1	345	86.00	51.3
262	65.25	106.9	304	75.75	45.7	346	86.25	50.7
263	65.50	101.3	305	76.00	45.7	347	86.50	47.2
264	65.75	96.7	306	76.25	50.7	348	86.75	49.7
265	66.00	92.7	307	76.50	59.1	349	87.00	56.5
266	66.25	90.1	308	76.75	68.3	350	87.25	59.8
267	66.50	88.3	309	77.00	78.2	351	87.50	60.6
268	66.75	87.6	310	77.25	82.8	352	87.75	60.7
269	67.00	87.7	311	77.50	83.5	353	88.00	60.2
270	67.25	86.5	312	77.75	81.6	354	88.25	62.1
271	67.50	84.4	313	78.00	77.8	355	88.50	65.9
272	67.75	82.3	314	78.25	74.0	356	88.75	71.6
273	68.00	80.5	315	78.50	70.2	357	89.00	78.9
274	68.25	74.2	316	78.75	68.9	358	89.25	82.4
275	68.50	64.8	317	79.00	69.4	359	89.50	83.4
276	68.75	66.5	318	79.25	71.8	360	89.75	83.8
277	69.00	75.7	319	79.50	75.5	361	90.00	83.8
278	69.25	83.0	320	79.75	77.2	362	90.25	83.4
279	69.50	89.0	321	80.00	77.3	363	90.50	82.6
280	69.75	94.6	322	80.25	77.2	364	90.75	80.2
281	70.00	100.0	323	80.50	77.0	365	91.00	76.7
282	70.25	105.7	324	80.75	74.6	366	91.25	71.1
283	70.50	111.8	325	81.00	70.7	367	91.50	64.0
284	70.75	114.3	326	81.25	69.1	368	91.75	64.0
285	71.00	114.3	327	81.50	69.0	369	92.00	69.1
286	71.25	112.1	328	81.75	69.0	370	92.25	72.7
287	71.50	108.2	329	82.00	68.9	371	92.50	75.2
288	71.75	104.3	330	82.25	68.8	372	92.75	76.2
289	72.00	100.4	331	82.50	68.6	373	93.00	76.2
290	72.25	96.0	332	82.75	68.6	374	93.25	76.2
291	72.50	91.1	333	83.00	68.6			
292	72.75	87.0	334	83.25	68.6			
293	73.00	83.4	335	83.50	68.6			
294	73.25	81.2	336	83.75	64.2			

Table 19. Ground types for test case CLSBDL.

i_{gr}, i_{gc}	$igrnd_i$[a]	$rgrnd_i$ (km)	γc (dB)	γrng (km)
1	4	0.	-7.	0.
2	3	45.	-10.	45.

[a]Ground composition type: 0=sea water; 1=fresh water; 2=wet ground; 3=medium dry ground; 4=very dry ground; 5=ice at -1°C; 6=ice at -10°C; 7=user-defined permittivity and conductivity.

Table 20. Terrain profile for test case CLSBDWL and HF10TER.

i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)
1	0	0	34	118.1818	100	67	136.9318	9
2	100	0	35	118.75	106	68	137.5	6
3	100.5682	2	36	119.3182	100	69	138.0682	5
4	101.1364	2	37	119.8864	108	70	138.6364	7
5	101.7045	2	38	120.4545	89	71	139.2045	5
6	102.2727	3	39	121.0227	90	72	139.7727	8
7	102.8409	4	40	121.5909	95	73	140.3409	14
8	103.4091	5	41	122.1591	89	74	140.9091	7
9	103.9773	4	42	122.7273	107	75	141.4773	12
10	104.5455	7	43	123.2955	97	76	142.0455	10
11	105.1136	6	44	123.8636	108	77	142.6136	8
12	105.6818	9	45	124.4318	87	78	143.1818	14
13	106.25	12	46	125	76	79	143.75	15
14	106.8182	9	47	125.5682	73	80	144.3182	18
15	107.3864	9	48	126.1364	88	81	144.8864	29
16	107.9545	8	49	126.7045	86	82	145.4545	78
17	108.5227	10	50	127.2727	101	83	146.0227	76
18	109.0909	19	51	127.8409	101	84	146.5909	89
19	109.6591	21	52	128.4091	92	85	147.1591	139
20	110.2273	27	53	128.9773	65	86	147.7273	168
21	110.7955	32	54	129.5455	62	87	148.2955	173
22	111.3636	32	55	130.1136	47	88	148.8636	184
23	111.9318	47	56	130.6818	59	89	149.4318	193
24	112.5	43	57	131.25	44	90	150	232
25	113.0682	58	58	131.8182	33	91	150.5682	227
26	113.6364	82	59	132.3864	21	92	151.1364	264
27	114.2045	75	60	132.9545	20	93	151.7045	222
28	114.7727	96	61	133.5227	21	94	152.2727	267
29	115.3409	63	62	134.0909	11	95	152.8409	247
30	115.9091	100	63	134.6591	7	96	153.4091	287
31	116.4773	123	64	135.2273	7	97	153.9773	363
32	117.0455	98	65	135.7955	4	98	154.5455	427
33	117.6136	95	66	136.3636	12	99	155.1136	399

Table 20. Terrain profile for test case CLSBDWL and HF10TER. (Continued)

i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)
100	155.6818	344	142	179.5455	682	184	203.4091	548
101	156.25	258	143	180.1136	544	185	203.9773	551
102	156.8182	188	144	180.6818	477	186	204.5455	546
103	157.3864	182	145	181.25	509	187	205.1136	545
104	157.9545	94	146	181.8182	510	188	205.6818	547
105	158.5227	85	147	182.3864	546	189	206.25	556
106	159.0909	63	148	182.9545	582	190	206.8182	569
107	159.6591	43	149	183.5227	844	191	207.3864	576
108	160.2273	18	150	184.0909	873	192	207.9545	610
109	160.7955	16	151	184.6591	776	193	208.5227	636
110	161.3636	16	152	185.2273	819	194	209.0909	634
111	161.9318	13	153	185.7955	830	195	209.6591	704
112	162.5	21	154	186.3636	814	196	210.2273	736
113	163.0682	20	155	186.9318	860	197	210.7955	719
114	163.6364	22	156	187.5	870	198	211.3636	702
115	164.2045	26	157	188.0682	993	199	211.9318	714
116	164.7727	27	158	188.6364	901	200	212.5	691
117	165.3409	31	159	189.2045	886	201	213.0682	676
118	165.9091	45	160	189.7727	946	202	213.6364	671
119	166.4773	58	161	190.3409	911	203	214.2045	671
120	167.0455	64	162	190.9091	1025	204	214.7727	708
121	167.6136	87	163	191.4773	1123	205	215.3409	668
122	168.1818	92	164	192.0455	1262	206	215.9091	674
123	168.75	112	165	192.6136	1424	207	216.4773	688
124	169.3182	124	166	193.1818	1460	208	217.0455	638
125	169.8864	144	167	193.75	1442	209	217.6136	661
126	170.4545	178	168	194.3182	1348	210	218.1818	652
127	171.0227	154	169	194.8864	1152	211	218.75	673
128	171.5909	172	170	195.4545	940	212	219.3182	673
129	172.1591	192	171	196.0227	1256	213	219.8864	665
130	172.7273	192	172	196.5909	1111	214	220.4545	703
131	173.2955	196	173	197.1591	943	215	221.0227	671
132	173.8636	216	174	197.7273	1037	216	221.5909	685
133	174.4318	222	175	198.2955	931	217	222.1591	730
134	175	234	176	198.8636	759	218	222.7273	722
135	175.5682	236	177	199.4318	673	219	223.2955	737
136	176.1364	262	178	200	702	220	223.8636	709
137	176.7045	287	179	200.5682	607	221	224.4318	752
138	177.2727	372	180	201.1364	649	222	225	767
139	177.8409	546	181	201.7045	576	223	225.5682	774
140	178.4091	699	182	202.2727	551	224	226.1364	728
141	178.9773	821	183	202.8409	548	225	226.7045	749

Table 20. Terrain profile for test case CLSBDWL and HF10TER. (Continued)

i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)
226	227.2727	761	240	235.2273	1094	254	243.1818	964
227	227.8409	759	241	235.7955	1249	255	243.75	897
228	228.4091	815	242	236.3636	1334	256	244.3182	861
229	228.9773	836	243	236.9318	1286	257	244.8864	806
230	229.5455	896	244	237.5	1235	258	245.4545	796
231	230.1136	924	245	238.0682	1181	259	246.0227	780
232	230.6818	956	246	238.6364	1165	260	246.5909	773
233	231.25	1136	247	239.2045	1196	261	247.1591	767
234	231.8182	1187	248	239.7727	1207	262	247.7273	764
235	232.3864	1353	249	240.3409	1257	263	248.2955	761
236	232.9545	1313	250	240.9091	1177	264	248.8636	753
237	233.5227	1153	251	241.4773	1237	265	249.4318	750
238	234.0909	1111	252	242.0455	1186			
239	234.6591	1095	253	242.6136	1085			

Table 21. Ground types for test case CLSBDWL

i_{gr}, i_{gc}	$igrnd_i$[a]	$rgrnd_i$ (km)	γc (dB)	γrng (km)
1	0	0.	-5.	0.
2	4	100.	-10.	100.

Table 22. Terrain profile for test case FLTA50.

i	$terx_i$ (km)	$tery_i$ (meters)
1	0.	10.
2	50.	10.

Table 23. Terrain profile for test case HEIGHT_RTG.

i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)
1	0.000	299.505	43	2.552	194.509	85	5.104	129.424
2	0.061	293.102	44	2.613	191.783	86	5.165	128.345
3	0.122	285.291	45	2.674	189.084	87	5.226	126.420
4	0.182	275.476	46	2.734	186.385	88	5.286	124.172
5	0.243	274.000	47	2.795	184.601	89	5.347	122.607
6	0.304	282.185	48	2.856	183.542	90	5.408	122.185
7	0.365	295.347	49	2.917	183.000	91	5.469	121.980
8	0.425	302.937	50	2.977	182.743	92	5.529	119.549
9	0.486	303.296	51	3.038	182.000	93	5.590	115.950
10	0.547	303.015	52	3.099	182.000	94	5.651	112.351
11	0.608	304.000	53	3.160	182.000	95	5.712	109.501
12	0.668	303.744	54	3.220	179.587	96	5.772	106.397
13	0.729	300.168	55	3.281	174.642	97	5.833	103.135
14	0.790	296.820	56	3.342	169.241	98	5.894	100.155
15	0.851	292.997	57	3.403	164.599	99	5.955	97.891
16	0.911	287.759	58	3.463	160.716	100	6.015	96.565
17	0.972	281.854	59	3.524	156.889	101	6.076	96.000
18	1.033	276.646	60	3.585	153.416	102	6.137	96.030
19	1.094	272.799	61	3.646	151.279	103	6.198	96.592
20	1.154	269.115	62	3.706	147.165	104	6.258	97.472
21	1.215	263.611	63	3.767	143.896	105	6.319	98.371
22	1.276	257.254	64	3.828	139.232	106	6.380	99.271
23	1.337	245.911	65	3.889	134.218	107	6.441	100.171
24	1.398	243.898	66	3.950	128.083	108	6.502	101.071
25	1.458	243.155	67	4.010	124.264	109	6.562	101.970
26	1.519	240.320	68	4.071	123.043	110	6.623	103.117
27	1.580	237.236	69	4.132	122.844	111	6.684	104.770
28	1.641	235.571	70	4.193	123.099	112	6.745	105.716
29	1.701	233.148	71	4.253	123.944	113	6.805	107.516
30	1.762	228.323	72	4.314	124.425	114	6.866	108.996
31	1.823	224.033	73	4.375	123.526	115	6.927	110.273
32	1.884	219.266	74	4.436	123.481	116	6.988	111.914
33	1.944	214.502	75	4.496	123.203	117	7.048	113.714
34	2.005	213.180	76	4.557	122.460	118	7.109	115.514
35	2.066	213.000	77	4.618	121.908	119	7.170	117.313
36	2.127	212.574	78	4.679	121.691	120	7.231	119.113
37	2.187	211.037	79	4.739	121.538	121	7.291	120.858
38	2.248	208.621	80	4.800	121.278	122	7.352	122.435
39	2.309	205.922	81	4.861	122.138	123	7.413	126.256
40	2.370	203.222	82	4.922	128.631	124	7.474	129.869
41	2.430	200.523	83	4.982	131.102	125	7.534	133.931
42	2.491	197.785	84	5.043	130.169	126	7.595	138.091

Table 23. Terrain profile for test case HEIGHT_RTG.

i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)
127	7.656	143.134	169	10.208	177.921	211	12.760	155.000
128	7.717	146.594	170	10.269	177.924	212	12.821	155.000
129	7.778	148.177	171	10.329	177.827	213	12.881	155.000
130	7.838	149.890	172	10.390	177.204	214	12.942	155.000
131	7.899	150.397	173	10.451	177.540	215	13.003	155.000
132	7.960	150.576	174	10.512	177.876	216	13.064	155.000
133	8.021	149.898	175	10.573	176.820	217	13.125	155.000
134	8.081	146.486	176	10.633	176.887	218	13.185	155.000
135	8.142	148.353	177	10.694	177.890	219	13.246	155.000
136	8.203	150.580	178	10.755	179.717	220	13.307	155.000
137	8.264	151.340	179	10.816	183.114	221	13.368	155.000
138	8.324	151.342	180	10.876	187.030	222	13.428	155.000
139	8.385	151.344	181	10.937	187.587	223	13.489	155.000
140	8.446	151.346	182	10.998	186.186	224	13.550	155.000
141	8.507	151.349	183	11.059	184.961	225	13.611	155.000
142	8.567	151.351	184	11.119	181.541	226	13.671	155.000
143	8.628	151.354	185	11.180	176.874	227	13.732	155.000
144	8.689	148.733	186	11.241	170.821	228	13.793	155.000
145	8.750	146.851	187	11.302	166.223	229	13.854	155.000
146	8.810	145.405	188	11.362	162.408	230	13.914	155.000
147	8.871	144.259	189	11.423	159.207	231	13.975	155.000
148	8.932	141.215	190	11.484	157.475	232	14.036	155.000
149	8.993	137.404	191	11.545	154.210	233	14.097	155.000
150	9.053	135.142	192	11.605	152.143	234	14.157	155.000
151	9.114	131.871	193	11.666	156.158	235	14.218	155.000
152	9.175	133.486	194	11.727	158.057	236	14.279	155.000
153	9.236	135.960	195	11.788	158.445	237	14.340	155.000
154	9.297	138.960	196	11.849	158.874	238	14.401	155.000
155	9.357	141.996	197	11.909	159.644	239	14.461	155.109
156	9.418	145.272	198	11.970	159.410	240	14.522	155.337
157	9.479	149.519	199	12.031	158.268	241	14.583	155.336
158	9.540	152.000	200	12.092	157.187	242	14.644	155.327
159	9.600	152.000	201	12.152	155.000	243	14.704	155.026
160	9.661	152.149	202	12.213	155.000	244	14.765	155.000
161	9.722	152.765	203	12.274	155.000	245	14.826	155.000
162	9.783	153.698	204	12.335	155.000	246	14.887	155.000
163	9.843	155.393	205	12.395	155.000	247	14.947	155.000
164	9.904	158.023	206	12.456	155.000	248	15.008	155.000
165	9.965	161.649	207	12.517	155.000	249	15.069	155.000
166	10.026	165.081	208	12.578	155.000	250	15.130	155.000
167	10.086	169.421	209	12.638	155.000	251	15.190	155.526
168	10.147	174.600	210	12.699	155.000	252	15.251	159.420

Table 23. Terrain profile for test case HEIGHT_RTG.

i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)
253	15.312	163.313	271	16.406	182.000	289	17.499	194.094
254	15.373	166.669	272	16.466	182.000	290	17.560	193.410
255	15.433	169.488	273	16.527	182.000	291	17.621	193.332
256	15.494	172.388	274	16.588	182.000	292	17.682	192.703
257	15.555	174.689	275	16.649	182.000	293	17.742	192.442
258	15.616	176.772	276	16.709	182.000	294	17.803	191.841
259	15.677	178.643	277	16.770	182.000	295	17.864	191.503
260	15.737	179.691	278	16.831	182.000	296	17.925	191.423
261	15.798	181.120	279	16.892	182.000	297	17.985	191.425
262	15.859	182.000	280	16.953	182.000	298	18.046	191.014
263	15.920	182.000	281	17.013	182.000	299	18.107	190.116
264	15.980	182.000	282	17.074	182.000	300	18.168	189.431
265	16.041	182.000	283	17.135	182.000	301	18.229	189.545
266	16.102	182.000	284	17.196	182.000	302	18.289	190.451
267	16.163	182.000	285	17.256	182.000	303	18.350	191.606
268	16.223	182.000	286	17.317	186.555	304	18.411	193.116
269	16.284	182.000	287	17.378	191.465			
270	16.345	182.000	288	17.439	193.821			

Table 24. Ground types for test case HF10TER.

i_{gr}, i_{gc}	$igrnd_i$ [a]	$rgrnd_i$ (km)	$dielec$ (ε_r, σ) [a]
1	7	0.	(80., 4.0)
2	7	80.	(5.0, 0.0001)

[a] ε_r = relative permittivity; σ = conductivity (S/m)

Table 25. Terrain profile for test case MPRT.

i	$terx_i$ (km)	$tery_i$ (meters)
1	0.	0.
2	10.	0.
3	30.	600.
4	50.	0.
5	60.	0.

Table 26. Terrain profile for test case PERW.

i	$terx_i$ (km)	$tery_i$ (meters)
1	0.	0.
2	18.75	0.
3	20.312	210.
4	21.875	320.
5	23.4375	375.
6	25.00	390.
7	26.565	375.
8	28.125	320.
9	31.250	90.
10	32.8125	0.
11	50.00	0.

Table 27. Terrain profile for test case PVT.

i	$terx_i$ (km)	$tery_I$ (meters)
1	0.00	625.
2	3.17	476.
3	6.34	347.
4	9.51	239.
5	12.69	151.
6	15.87	83.
7	19.04	35.
8	22.22	7.
9	25.00	0.
10	27.78	7.
11	30.96	35.
12	34.13	83.
13	37.13	151.
14	40.49	239.
15	43.66	347.
16	46.83	476.
17	50.	625.

Table 28. Terrain profile for test case RDLONGB and TROPOT.

i	$terx_i$ (km)	$tery_I$ (meters)	i	$terx_i$ (km)	$tery_I$ (meters)	i	$terx_i$ (km)	$tery_I$ (meters)
1	0.0	8.0	57	20.10	22.0	113	79.20	184.0
2	.30	8.0	58	20.40	23.0	114	79.50	226.0
3	.60	9.0	59	20.70	24.0	115	79.80	152.0
4	.90	9.0	60	21.00	24.0	116	80.10	201.0
5	1.20	10.0	61	21.30	25.0	117	80.40	244.0
6	1.50	11.0	62	21.60	26.0	118	80.70	152.0
7	1.80	12.0	63	21.90	27.0	119	81.00	143.0
8	2.10	13.0	64	22.20	27.0	120	81.30	91.0
9	2.40	14.0	65	22.50	28.0	121	81.60	107.0
10	2.70	15.0	66	22.80	29.0	122	81.90	152.0
11	3.00	17.0	67	23.40	29.0	123	82.20	152.0
12	3.30	19.0	68	23.70	30.0	124	82.50	170.0
13	3.60	21.0	69	24.60	30.0	125	82.80	152.0
14	3.90	23.0	70	24.90	32.0	126	83.10	66.0
15	4.20	25.0	71	25.20	34.0	127	83.40	70.0
16	4.50	27.0	72	25.50	38.0	128	83.70	121.0
17	4.80	28.0	73	26.10	38.0	129	84.00	152.0
18	5.10	30.0	74	26.40	36.0	130	84.30	170.0
19	5.40	31.0	75	26.70	34.0	131	84.60	141.0
20	5.70	31.0	76	27.00	32.0	132	84.90	139.0
21	6.00	29.0	77	27.30	27.0	133	85.20	147.0
22	6.30	23.0	78	27.60	15.0	134	85.50	177.0
23	6.60	14.0	79	27.90	6.0	135	85.80	152.0
24	6.90	9.0	80	28.20	1.0	136	86.10	61.0
25	7.20	7.0	81	28.50	0.0	137	86.70	61.0
26	7.50	7.0	82	64.50	0.0	138	87.00	70.0
27	7.80	9.0	83	64.80	8.0	139	87.30	44.0
28	8.10	11.0	84	65.10	30.0	140	87.60	11.0
29	8.40	14.0	85	65.40	39.0	141	87.90	1.0
30	8.70	13.0	86	65.70	61.0	142	89.40	1.0
31	9.30	13.0	87	66.60	61.0	143	89.70	61.0
32	9.60	12.0	88	66.90	24.0	144	90.00	84.0
33	9.90	11.0	89	67.20	14.0	145	90.30	152.0
34	10.20	8.0	90	67.50	26.0	146	90.60	152.0
35	10.80	8.0	91	67.80	16.0	147	90.90	101.0
36	11.10	7.0	92	68.10	1.0	148	91.20	40.0
37	12.60	7.0	93	68.40	1.0	149	91.50	15.0
38	12.90	6.0	94	68.70	0.0	150	91.80	20.0

Table 28. Terrain profile for test case RDLONGB and TROPOT.

i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)	i	$terx_i$ (km)	$tery_i$ (meters)
39	14.40	6.0	95	73.80	0.0	151	92.10	2.0
40	14.70	7.0	96	74.10	1.0	152	92.40	10.0
41	15.00	8.0	97	74.40	1.0	153	92.70	4.0
42	15.30	8.0	98	74.70	10.0	154	93.00	1.0
43	15.60	9.0	99	75.00	8.0	155	93.30	1.0
44	15.90	10.0	100	75.30	39.0	156	93.60	0.0
45	16.20	11.0	101	75.60	45.0	157	93.90	1.0
46	16.50	11.0	102	75.90	53.0	158	96.30	1.0
47	16.80	12.0	103	76.20	61.0	159	96.60	0.0
48	17.40	12.0	104	76.50	61.0	160	96.90	1.0
49	17.70	13.0	105	76.80	82.0	161	97.50	1.0
50	18.00	13.0	106	77.10	61.0	162	97.80	2.0
51	18.30	14.0	107	77.40	78.0	163	98.10	3.0
52	18.60	15.0	108	77.70	61.0	164	99.30	3.0
53	18.90	16.0	109	78.00	129.0	165	99.60	2.0
54	19.20	18.0	110	78.30	30.0	166	99.90	2.0
55	19.50	20.0	111	78.60	46.0	167	100.20	1.0
56	19.80	21.0	112	78.90	159.0			

Table 29. Ground types for test case RDLONGB and TROPOT.

i_{gr}	$igrnd_i$[a]	$rgrnd_i$ (km)
1	2	0.
2	0	28.5
3	3	64.8
4	0	68.7
5	4	74.1
6	0	100.2

[a]Ground composition type: 0=sea water; 1=fresh water; 2=wet ground; 3=medium dry ground; 4=very dry ground; 5=ice at -1°C; 6=ice at -10°C; 7=user-defined permittivity and conductivity.

Table 30. Terrain profile for test case VERTMIX.

i	$terx_i$ (km)	$tery_i$ (meters)	i_{gr}	$igrnd_i$[a]	$rgrnd_i$ (km)
1	0.	0.	1	4	0.
2	50.	0.	2	0	25.0

[a]Ground composition type: 0=sea water; 1=fresh water; 2=wet ground; 3=medium dry ground; 4=very dry ground; 5=ice at -1°C; 6=ice at -10°C; 7=user-defined permittivity and conductivity.

Table 31. Terrain profile for test case VERTUSRD.

i	$terx_i$ (km)	$tery_i$ (meters)
1	0.	0.
2	50.	0.

Table 32. Terrain profile for test case WEDGE.

i	$terx_i$ (km)	$tery_i$ (meters)
1	0.	0.
2	45.0	0.
3	50.0	200.
4	55.0	0.
5	100.0	0.

4.4 EXPECTED TEST RESULTS

The expected test results listing propagation loss versus height values for each of the 48 test cases are listed in tabular form inTable 33 through Table 80.

Table 33. Expected output for ABSORB for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
10.0	212.7	-60.2
20.0	199.3	-46.8
30.0	188.9	-36.5
40.0	180.1	-27.6
50.0	172.2	-19.8
60.0	165.5	-13
70.0	160.1	-7.6
80.0	156.7	-4.3
90.0	156.5	-4
100.0	163.2	-10.7
110.0	159.3	-6.9
120.0	156	-3.6
130.0	167.8	-15.3
140.0	155.7	-3.3
150.0	163	-10.5
160.0	156.1	-3.6
170.0	161.9	-9.4
180.0	155.7	-3.3
190.0	164.5	-12
200.0	154.9	-2.5

Table 34. Expected output for AFEVAP for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
50	133.7	2.3
100	143.8	-7.8
150	135.8	0.2
200	131.1	4.9
250	142	-6.1
300	132.1	3.9
350	133.1	2.8
400	135.7	0.2
450	131.2	4.8
500	139.7	-3.7
550	130.4	5.6
600	146.5	-10.5
650	130.1	5.8
700	163.8	-27.8
750	130.1	5.9
800	154.5	-18.6
850	130.1	5.9
900	147.1	-11.2
950	130.2	5.8
1000	142.8	-6.8

Table 35. Expected output for AFSBD for r_{max} receiver range of 100 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
150	138.8	3.2
300	166.3	-24.3
450	156.2	-14.2
600	143.1	-1.1
750	140.1	1.9
900	148.9	-6.9
1050	138	4
1200	143.9	-1.9
1350	139.7	2.3
1500	138	4
1650	155.6	-13.6
1800	137.1	4.9
1950	139.6	2.4
2100	147.8	-5.8
2250	136.8	5.2
2400	139.1	2.8
2550	151.9	-9.9
2700	137.2	4.8
2850	137.5	4.5
3000	155.1	-13.1

Table 36. Expected Output for AFSTD for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
50	143.8	-17.4
100	133.6	-7.2
150	127.3	-0.8
200	123.3	3.1
250	121.3	5.2
300	121.1	5.3
350	123.2	3.3
400	129.7	-3.3
450	137.6	-11.2
500	124.9	1.5
550	121.3	5.1
600	120.6	5.8
650	122.3	4.1
700	128.1	-1.7
750	141.2	-14.8
800	125.3	1.1
850	121.3	5.1
900	120.5	5.9
950	122.1	4.3
1000	127.6	-1.1

Table 37. Expected Output for AIRBORNE for r_{max} receiver range of 250 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
250	136.9	2.6
500	136	3.5
750	138.1	1.4
1000	140	-0.5
1250	138.2	1.3
1500	133.1	6.4
1750	142.8	-3.3
2000	142.4	-2.9
2250	143	-3.5
2500	142.4	-2.9
2750	141.9	-2.4
3000	136.9	2.6
3250	141	-1.5
3500	141	-1.5
3750	139.5	0
4000	143.2	-3.7
4250	140	-0.5
4500	144	-4.5
4750	138.4	1.1
5000	138.9	0.6

Table 38. Expected output for BLOCK for r_{max} receiver range of 60 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
0	-3276.6	-3276.6
20	216.1	-88.1
40	209.4	-81.4
60	207.8	-79.8
80	209	-81
100	207.2	-79.2
120	203	-75
140	200.7	-72.7
160	198.6	-70.6
180	195.1	-67
200	191.6	-63.6
220	188.2	-60.2
240	184.4	-56.4
260	180.6	-52.6
280	176.9	-48.9
300	173.3	-45.3
320	170	-42
340	167.1	-39.1
360	164.7	-36.7
380	162.6	-34.6
400	160.7	-32.7

Table 39. Expected output for CLEVAPW for receiver height of 0 and 500 m, plus clutter-to-noise ratio (CNR).

	Rec. height at 0 m		Rec. height at 500 m		
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	CNR (dB)
1	119.9	-7.4	143.8	-30.5	53.1
2	121.7	-3.3	149.2	-30.5	52.2
3	-3276.7	-3276.7	152.5	-30.4	46.5
4	-3276.7	-3276.7	155	-30.5	40
5	133.2	-6.8	156.9	-30.4	38.9
6	135.8	-7.8	158.5	-30.5	34.7
7	137.8	-8.4	159.7	-30.4	31.6
8	139.5	-9	160.9	-30.3	28.8
9	141.1	-9.6	162.1	-30.6	26.2
10	142.6	-10.2	162.7	-30.3	23.7
11	144	-10.7	163.9	-30.7	21.5
12	145.2	-11.2	166	-32	19.5
13	146.3	-11.6	154.8	-20	17.7
14	147.3	-11.9	150.1	-14.7	16
15	148.2	-12.2	147.6	-11.6	14.6
16	149	-12.5	146.4	-9.9	13.3
17	149.8	-12.7	145.2	-8.1	12
18	150.5	-13	144.9	-7.4	10.7
19	151.3	-13.3	143.8	-5.8	9.4
20	152	-13.6	144.2	-5.7	8.2
21	152.8	-13.9	144.2	-5.3	6.9
22	153.5	-14.2	143.8	-4.5	5.7
23	154.2	-14.5	142.9	-3.2	4.5
24	154.9	-14.8	143.9	-3.9	3.3
25	155.5	-15.1	142.9	-2.5	2.2
26	156.1	-15.4	144.3	-3.6	1.1
27	156.8	-15.7	143.7	-2.7	0
28	157.4	-16	143	-1.7	-1.1
29	158	-16.3	143	-1.3	-2.1
30	158.5	-16.5	143.1	-1.1	-3
31	159.1	-16.8	143.2	-0.9	-3.9
32	159.6	-17	143.3	-0.8	-4.9
33	160.1	-17.3	144	-1.2	-5.7
34	160.6	-17.5	145.4	-2.4	-6.6

Table 39. Expected output for CLEVAPW for receiver height of 0 and 500 m, plus clutter-to-noise ratio (CNR).

	Rec. height at 0 m		Rec. height at 500 m		
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	CNR (dB)
35	161	-17.7	145.4	-2	-6.6
36	161.4	-17.9	143.8	-0.2	-7.3
37	161.8	-18	144.6	-0.8	-8
38	162.2	-18.1	146.4	-2.4	-9.2
39	162.5	-18.2	144.1	0.1	-9.8
40	162.9	-18.4	145.9	-1.5	-10.4
41	163.2	-18.5	145.5	-0.8	-11
42	163.6	-18.6	145.1	-0.2	-11.6
43	163.9	-18.8	146.7	-1.6	-12.2
44	164.2	-18.9	145	0.3	-12.7
45	164.6	-19.1	147.1	-1.6	-13.3
46	164.9	-19.2	145.5	0.2	-13.8
47	165.2	-19.3	146.6	-0.7	-14.4
48	165.5	-19.5	146.9	-0.8	-14.9
49	165.8	-19.6	145.6	0.6	-15.5
50	166.2	-19.8	148.9	-2.4	-16.1
51	166.5	-19.9	145.6	1	-16.7
52	166.9	-20.1	147.7	-1	-17.3
53	167.2	-20.3	148.2	-1.2	-17.9
54	167.6	-20.5	145.8	1.3	-18.6
55	168	-20.7	149	-1.7	-19.2
56	168.4	-20.9	148.3	-0.9	-19.9
57	168.7	-21.2	146.1	1.4	-20.6
58	169.1	-21.4	148.9	-1.2	-21.3
59	169.5	-21.6	149.7	-1.9	-22
60	169.9	-21.9	146.7	1.3	-22.7
61	170.2	-22.1	147.7	0.4	-23.3
62	170.6	-22.3	151.2	-2.9	-23.9
63	170.9	-22.4	146.2	2.2	-24.5
64	171.2	-22.6	148.1	0.5	-25
65	171.5	-22.8	152	-3.3	-25.5
66	171.7	-22.9	152.1	-3.3	-26
67	172	-23	148.7	0.3	-26.4
68	172.2	-23.1	147	2.1	-26.8
69	172.4	-23.2	147.6	1.6	-27.2
70	172.7	-23.3	150.1	-0.7	-27.5

Table 39. Expected output for CLEVAPW for receiver height of 0 and 500 m, plus clutter-to-noise ratio (CNR).

	Rec. height at 0 m		Rec. height at 500 m		
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	CNR (dB)
71	172.9	-23.4	153.6	-4.2	-27.9
72	173.1	-23.5	151.7	-2.1	-28.2
73	173.3	-23.5	147.8	1.9	-28.6
74	173.5	-23.6	147.7	2.1	-28.9
75	173.7	-23.7	151.2	-1.3	-29.3
76	173.9	-23.8	155.2	-5.1	-29.6
77	174.1	-23.9	152.6	-2.4	-30
78	174.3	-24	148.8	1.5	-30.4
79	174.5	-24.1	148.1	2.3	-30.8
80	174.8	-24.2	149.8	0.7	-31.2
81	175	-24.4	154	-3.4	-31.6
82	175.2	-24.5	155.9	-5.2	-32
83	175.5	-24.7	152	-1.2	-32.5
84	175.7	-24.8	149.6	1.3	-32.9
85	176	-25	149	2	-33.4
86	176.3	-25.1	150	1.2	-33.9
87	176.5	-25.3	152.5	-1.3	-34.3
88	176.8	-25.5	156.8	-5.5	-34.8
89	177	-25.6	159.4	-7.9	-35.3
90	177.3	-25.8	157	-5.5	-35.8
91	177.6	-25.9	153.5	-1.8	-36.2
92	177.8	-26.1	151.4	0.3	-36.7
93	178	-26.2	150.6	1.3	-37.1
94	178.3	-26.4	150.6	1.4	-37.5
95	178.5	-26.5	151.3	0.7	-37.9
96	178.7	-26.6	152.7	-0.6	-38.3
97	178.9	-26.8	154.8	-2.7	-38.7
98	179.2	-26.9	157.9	-5.6	-39.1
99	179.4	-27	161.5	-9.1	-39.4
100	179.6	-27.1	162.8	-10.3	-39.8

Table 40. Expected output for CLSBDL for receiver height of 500 and 1000 m, plus clutter-to-noise ratio (CNR).

	Rec. height at 500 m		Rec. height at 1000 m		
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	CNR (dB)
1	-3276.7	-3276.7	-3276.7	-3276.7	-33.7
2	-3276.7	-3276.7	-3276.7	-3276.7	54.8
3	-3276.7	-3276.7	-3276.7	-3276.7	81.8
4	-3276.7	-3276.7	-3276.7	-3276.7	80.1
5	-3276.7	-3276.7	-3276.7	-3276.7	36.8
6	-3276.7	-3276.7	-3276.7	-3276.7	28.1
7	-3276.7	-3276.7	-3276.7	-3276.7	65.3
8	-3276.7	-3276.7	-3276.7	-3276.7	88.7
9	-3276.7	-3276.7	-3276.7	-3276.7	76.9
10	-3276.7	-3276.7	-3276.7	-3276.7	90.8
11	-3276.7	-3276.7	-3276.7	-3276.7	77.6
12	-3276.7	-3276.7	-3276.7	-3276.7	89.9
13	-3276.7	-3276.7	-3276.7	-3276.7	59.2
14	-3276.7	-3276.7	-3276.7	-3276.7	64.5
15	-3276.7	-3276.7	-3276.7	-3276.7	67.3
16	-3276.7	-3276.7	-3276.7	-3276.7	56.8
17	-3276.7	-3276.7	-3276.7	-3276.7	61.7
18	-3276.7	-3276.7	-3276.7	-3276.7	64
19	-3276.7	-3276.7	-3276.7	-3276.7	64.5
20	-3276.7	-3276.7	-3276.7	-3276.7	46.3
21	-3276.7	-3276.7	-3276.7	-3276.7	71.5
22	-3276.7	-3276.7	-3276.7	-3276.7	47.9
23	-3276.7	-3276.7	-3276.7	-3276.7	57.8
24	-3276.7	-3276.7	-3276.7	-3276.7	46.2
25	129.5	0.5	-3276.7	-3276.7	59.1
26	130.8	-0.5	-3276.7	-3276.7	93.3
27	130.3	0.3	-3276.7	-3276.7	61
28	131.9	-1	-3276.7	-3276.7	96.5
29	132	-0.8	-3276.7	-3276.7	82.1
30	131.6	-0.1	-3276.7	-3276.7	42.4
31	133.2	-1.4	-3276.7	-3276.7	35.2
32	131.7	0.4	-3276.7	-3276.7	49.5
33	132.7	-0.4	-3276.7	-3276.7	14.4
34	133	-0.4	-3276.7	-3276.7	30.6
35	134.1	-1.2	-3276.7	-3276.7	34.5
36	134.3	-1.2	-3276.7	-3276.7	19.7

Table 40. Expected output for CLSBDL for receiver height of 500 and 1000 m, plus clutter-to-noise ratio (CNR).

	Rec. height at 500 m		Rec. height at 1000 m		
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	CNR (dB)
37	135.2	-1.8	-3276.7	-3276.7	46.3
38	135.4	-1.8	-3276.7	-3276.7	75.5
39	134.2	-0.4	-3276.7	-3276.7	54
40	136	-2	-3276.7	-3276.7	28.6
41	134.8	-0.6	-3276.7	-3276.7	50.2
42	135.6	-1.2	-3276.7	-3276.7	86.6
43	135.1	-0.5	-3276.7	-3276.7	46.6
44	135.9	-1.1	-3276.7	-3276.7	43.7
45	136.8	-1.7	-3276.7	-3276.7	30.6
46	136.9	-1.7	-3276.7	-3276.7	5.1
47	136.5	-1	-3276.7	-3276.7	-20.6
48	137.5	-1.9	-3276.7	-3276.7	-8.9
49	137.1	-1.3	-3276.7	-3276.7	11.4
50	138.3	-2.4	-3276.7	-3276.7	3.9
51	136.9	-0.7	-3276.7	-3276.7	27.1
52	137.2	-0.9	-3276.7	-3276.7	-14.6
53	137.7	-1.2	136.4	0	23.6
54	138.5	-1.9	136.1	0.5	48.3
55	139.4	-2.6	136.5	0.3	39.6
56	138.3	-1.3	137.2	-0.3	74.3
57	139.6	-2.5	138.3	-1.2	67.9
58	141.3	-4	138.6	-1.3	73.9
59	138.9	-1.5	138.2	-0.8	94.5
60	139.3	-1.8	138.6	-1.1	53.8
61	141.1	-3.4	138.9	-1.2	86
62	143.1	-5.3	138.6	-0.7	92.2
63	138.7	-0.8	139.6	-1.6	88.1
64	144.7	-6.6	138.7	-0.5	51.8
65	143.9	-5.7	139.8	-1.6	61.8
66	141.8	-3.5	139.2	-0.9	22.4
67	143.8	-5.3	139.6	-1.1	37.2
68	140.2	-1.6	139.6	-0.9	27.4
69	142.1	-3.3	140.6	-1.8	37.1
70	142.6	-3.7	139.8	-0.9	77.5
71	146.4	-7.4	142.2	-3.2	70.3
72	143.3	-4.2	140.3	-1.2	29.1

Table 40. Expected output for CLSBDL for receiver height of 500 and 1000 m, plus clutter-to-noise ratio (CNR).

	Rec. height at 500 m		Rec. height at 1000 m		
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	CNR (dB)
73	146.3	-7.1	139.6	-0.4	15.1
74	151.9	-12.6	142.2	-2.9	22
75	140.3	-0.8	139.7	-0.2	-1.6
76	143.7	-4.1	142.4	-2.8	5
77	147.3	-7.5	141.6	-1.8	48
78	158	-18.2	139.7	0.1	29.5
79	150.2	-10.3	142.4	-2.4	29.6
80	144.9	-4.9	142.8	-2.8	46.6
81	150	-9.9	141	-0.8	21.6
82	147.8	-7.5	141.9	-1.7	30.3
83	148.8	-8.4	142.1	-1.7	38.5
84	156.8	-16.3	142.5	-2.1	1.5
85	147.6	-7	144.5	-4	18.6
86	144.7	-4.1	143.9	-3.2	32.3
87	145.2	-4.4	141.1	-0.3	51.8
88	154.3	-13.5	140.6	0.3	36.3
89	146.9	-6	142	-1.1	77.7
90	147.5	-6.4	142.7	-1.6	53.4
91	163.6	-22.4	142.3	-1.1	13.4
92	150.9	-9.7	142.5	-1.2	17.4
93	147.9	-6.5	143.1	-1.8	50.1
94	153.3	-11.9	143.2	-1.8	48.1
95	149.8	-8.2	143.6	-2	39.5
96	151.5	-9.8	143.7	-2.1	46.8
97	147.9	-6.2	142.7	-1	53.2
98	149.8	-8	144.9	-3.1	48
99	157.8	-15.9	148	-6.1	39.6
100	161.9	-20	149.3	-7.3	47.4

Table 41. Expected output for CLSBDW for receiver height of 500 and 1000 m, plus clutter-to-noise ratio (CNR).

	Rec. height at 500 m		Rec. height at 1000 m		
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	CNR (dB)
1	102.9	0	104.9	0	91.8
2	108.3	0	109	0	90.9
3	111.6	0	112	0	81.3
4	114.1	0	114.3	0	72.4
5	116	0	116.1	0	65.2
6	117.6	0	117.7	0	59.3
7	118.9	0	119	0	53.6
8	120	0	120.1	0	48.1
9	121.1	0	121.1	0	42.8
10	122	0	122	0	36.9
11	122.8	0	122.9	0	33
12	123.6	0	123.6	0	29.5
13	124.3	0	124.3	0	26.2
14	124.9	0	124.9	0	22.9
15	125.5	0	125.5	0	19.6
16	126.1	0	126.1	0	16.3
17	126.6	0	126.6	0	13.5
18	127.1	0	127.1	0	10.5
19	127.5	0	127.6	0	7.5
20	128	0	128.1	0	4.2
21	128.4	0	128.5	-0.1	1
22	128.8	0	128.9	-0.1	-0.9
23	129.2	0	129.3	-0.1	-4.7
24	129.6	0	129.7	-0.1	-7.1
25	129.9	0	130	-0.1	-10.6
26	130.3	0	130.4	-0.1	-12.5
27	130.6	0	130.7	-0.1	-20.9
28	130.9	0	131	-0.1	-19
29	131.2	0	131.3	-0.1	-18.6
30	131.5	0	131.6	-0.1	-28.3
31	131.8	0	131.9	-0.1	-29
32	132.1	0	132.2	-0.1	-28
33	132.4	0	132.5	-0.1	-37.6
34	132.5	0.1	132.8	-0.1	-37.5
35	132.9	-0.1	133	-0.1	-27.7
36	133.5	-0.4	133.3	-0.2	-47.2

Table 41. Expected output for CLSBDW for receiver height of 500 and 1000 m, plus clutter-to-noise ratio (CNR).

	Rec. height at 500 m		Rec. height at 1000 m		
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	CNR (dB)
37	134.1	-0.8	133.5	-0.2	-36.2
38	134.3	-0.7	133.8	-0.2	-34.1
39	134.2	-0.4	134	-0.2	-38.5
40	133.8	0.3	134.2	-0.2	-36.1
41	133.3	0.9	134.4	-0.2	-32.7
42	133.2	1.3	134.7	-0.2	-45.9
43	133.3	1.4	134.9	-0.2	-25.8
44	133.8	1.1	135.1	-0.2	-30.2
45	134.6	0.5	135.3	-0.2	-30
46	135.6	-0.4	135.5	-0.3	-36.2
47	136.9	-1.5	135.7	-0.3	-25
48	138.2	-2.6	135.9	-0.3	-24.2
49	139.3	-3.5	136.1	-0.3	-43.7
50	139.8	-3.8	136.3	-0.3	-20.8
51	139.5	-3.3	136.5	-0.3	-20.3
52	138.6	-2.3	136.6	-0.3	-23.6
53	137.9	-1.4	136.8	-0.3	-25.6
54	137.1	-0.4	137	-0.4	-39.7
55	136.4	0.4	137.2	-0.4	-27
56	135.9	1.1	137.3	-0.4	-15.2
57	135.5	1.6	137.5	-0.4	-12.6
58	135.3	1.9	137.7	-0.4	-16.7
59	135.3	2.1	137.8	-0.4	-17.7
60	135.3	2.3	138	-0.5	-8.8
61	135.4	2.3	138.2	-0.5	-2.8
62	135.7	2.1	138.3	-0.5	-1.7
63	136	2	138.4	-0.4	-4.5
64	136.4	1.7	138.5	-0.4	-2.2
65	137	1.3	138.7	-0.5	3.3
66	137.5	0.9	139	-0.6	5.8
67	138.1	0.4	139.3	-0.8	6.9
68	138.8	-0.2	139.7	-1.1	8.6
69	139.6	-0.8	140.1	-1.3	10
70	140.4	-1.5	140.3	-1.4	10.6
71	141.2	-2.2	140.4	-1.4	11.7
72	142.2	-3	140.3	-1.2	14

Table 41. Expected output for CLSBDW for receiver height of 500 and 1000 m, plus clutter-to-noise ratio (CNR).

	Rec. height at 500 m		Rec. height at 1000 m		
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	CNR (dB)
73	143.2	-3.9	140.1	-0.9	16.8
74	144.2	-4.8	139.8	-0.5	19.3
75	145.2	-5.7	139.6	-0.1	21.8
76	146.4	-6.8	139.4	0.2	24.6
77	147.6	-7.9	139.2	0.5	27.7
78	148.7	-8.9	139.2	0.6	30.9
79	149.8	-9.9	139.3	0.7	39
80	151	-11	139.5	0.5	43.2
81	152	-11.8	139.9	0.3	46.1
82	153.2	-13	140.3	-0.1	49
83	153.8	-13.4	141	-0.6	51.8
84	154.7	-14.2	141.7	-1.2	54.4
85	155.4	-14.8	142.5	-1.9	56.6
86	156	-15.3	143.4	-2.7	58.2
87	156.7	-15.9	144.2	-3.5	59.4
88	156.8	-15.9	145	-4.1	60.2
89	156.9	-15.9	145.5	-4.6	60.6
90	157.2	-16.1	145.7	-4.7	60.3
91	157.3	-16.1	145.6	-4.4	59.7
92	158	-16.7	145.1	-3.9	58.5
93	157.7	-16.4	144.4	-3	56.7
94	158.4	-17	143.8	-2.3	55
95	157.8	-16.2	143.2	-1.7	52.6
96	158.8	-17.1	142.7	-1	50.9
97	159.6	-17.9	142.2	-0.4	48.7
98	159.4	-17.5	141.8	0	46.7
99	160.3	-18.4	141.5	0.4	44.3
100	160.3	-18.3	141.2	0.8	40.6

Table 42. Expected output for CLSBDWL for receiver height of 1500 and 3000 m, plus clutter-to-noise ratio (CNR).

	Rec. height at 1500 m		Rec. height at 3000 m		
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	CNR (dB)
2	145.8	-30.5	149	-30.5	58.3
4	150.4	-30.4	151.9	-30.5	39.7
6	134.2	-11	154.3	-30.4	25.6
8	131.3	-5.7	156.4	-30.4	14.3
10	131	-3.4	147.9	-20.1	3.5
12	131.6	-2.5	140.2	-11	-4.5
14	132	-1.6	138.2	-7.7	-11.9
16	132.9	-1.3	137.2	-5.5	-19.1
18	133.1	-0.6	136.6	-4	-26.1
20	134.1	-0.7	136.6	-3.1	-33
22	135.3	-1.1	137.4	-3	-39.7
24	135.2	-0.2	137.3	-2.2	-46.2
26	136.9	-1.1	137.4	-1.6	-52.2
28	136.2	0.2	138.1	-1.7	-57.8
30	136.6	0.3	138.5	-1.5	-69
32	137.9	-0.4	138.7	-1.2	-73.3
34	138.7	-0.6	139.4	-1.4	-93.1
36	139.1	-0.5	139.9	-1.3	-80.2
38	138.3	0.7	139.6	-0.6	-84.8
40	138.9	0.6	140.7	-1.3	-87.2
42	139.4	0.5	141.2	-1.3	-83.9
44	139.5	0.8	141.2	-0.9	-92.5
46	139.8	0.8	140.7	0	-76.5
48	141.5	-0.4	142.2	-1.2	-73.5
50	143.2	-1.8	141.3	0.1	-97.2
52	141	0.8	142.8	-1	-71.1
54	142.2	-0.2	143.1	-1	-67.6
56	143.4	-1.1	142.7	-0.3	-67.1
58	141.8	0.9	142.6	0.1	-72.4
60	144.7	-1.7	142.8	0.2	-61.4
62	142.4	0.9	143.3	0	-71.8
64	144.5	-1	144.1	-0.6	-44
66	144.1	-0.3	145.1	-1.3	-39.8
68	143.1	1	144.9	-0.8	-38.2
70	147.3	-3	143.8	0.5	-40.2
72	143.4	1.1	144.5	0	-34.4

Table 42. Expected output for CLSBDWL for receiver height of 1500 and 3000 m, plus clutter-to-noise ratio (CNR).

	Rec. height at 1500 m		Rec. height at 3000 m		
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	CNR (dB)
74	144.5	0.3	146.3	-1.5	-24.4
76	148.3	-3.3	144.5	0.5	-12.7
78	144.3	1	145.7	-0.5	-1.8
80	144.3	1.2	146.1	-0.6	11.4
82	148.8	-3.1	145.2	0.5	18.3
84	147.4	-1.5	147.2	-1.3	21.6
86	144.4	1.7	145.4	0.7	18.1
88	145.3	1	147.6	-1.3	-10
90	149.9	-3.4	146	0.5	14
92	149.6	-2.9	147.3	-0.6	20.9
94	145.7	1.1	147.4	-0.5	19.3
96	145	2	146.4	0.7	19.8
98	147.2	0.1	149.3	-2.1	12.8
100	152.1	-4.7	146.5	0.9	6.8
102	151.5	-4	148.1	-0.5	-19.3
104	147.4	0.3	149.2	-1.5	2.9
106	145.8	2.1	146.7	1.2	30
108	146.2	1.8	149	-0.9	11.1
110	148.7	-0.4	149.9	-1.6	13
112	153.4	-5	147.2	1.2	26
114	155.3	-6.7	148.7	-0.1	-13.7
116	150.6	-1.9	151.4	-2.7	17.4
118	147.9	1	148.4	0.4	-30.8
120	146.8	2.2	147.8	1.2	-32
122	147	2.1	150.8	-1.7	-53.7
124	148.4	0.9	151.6	-2.3	-48.8
126	151.2	-1.8	148.5	0.9	-62.1
128	155.8	-6.3	148.3	1.2	-58.9
130	159.9	-10.3	151.2	-1.6	-118.4
132	154.7	-4.9	153	-3.2	-101.4
134	151.4	-1.5	149.8	0.2	-108
136	149.4	0.7	148.5	1.6	-102.2
138	148.5	1.7	149.9	0.3	-74
140	148.1	2.2	153.6	-3.2	-96.4
142	148.3	2.2	153.4	-2.9	-68.5
144	149	1.6	150.1	0.5	-66.6

Table 42. Expected output for CLSBDWL for receiver height of 1500 and 3000 m, plus clutter-to-noise ratio (CNR).

	Rec. height at 1500 m		Rec. height at 3000 m		
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	CNR (dB)
146	151.2	-0.5	148.9	1.8	-44.6
148	152.4	-1.5	150	0.8	8.1
150	158.1	-7.2	153.4	-2.5	14.6
152	159.8	-8.7	155.8	-4.8	-29.4
154	161.7	-10.6	152.6	-1.4	-31.9
156	168.8	-17.5	150	1.2	-267.8
158	167.5	-16.1	149.5	1.9	-317.4
160	158.4	-6.9	150.7	0.8	-297.7
162	160.4	-8.8	153.9	-2.3	-246.4
164	157.9	-6.2	157.6	-5.9	-88.4
166	154.9	-3.1	155.2	-3.4	-76.9
168	155.5	-3.6	151.9	0	-71.1
170	156.1	-4.1	150.3	1.7	-79.3
172	155.8	-3.6	150.1	2	-82.4
174	156.1	-3.9	151.3	1	-82.5
176	157	-4.7	153.9	-1.6	-87.2
178	157	-4.6	158.1	-5.7	-30.8
180	158.8	-6.2	159.8	-7.3	-328.1
182	161.7	-9	155.9	-3.3	-319.2
184	165.1	-12.4	152.9	-0.2	-66.9
186	162.4	-9.6	151.3	1.5	-114.6
188	163.5	-10.6	150.8	2.1	-22
190	171.5	-18.5	151.3	1.7	-93.4
192	161	-8	152.6	0.5	-21.5
194	179.5	-26.4	155	-1.8	-225.5
196	180	-26.7	158.9	-5.6	-389
198	193.2	-39.8	170.4	-17	-388
200	196	-42.6	160.4	-7	-391.4

Table 43. Expected output for COSEC2 for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
100	134.4	-8
200	124.1	2.3
300	122.3	4.1
400	129.7	-3.3
500	126.5	-0.1
600	123.5	2.9
700	128	-1.6
800	126.9	-0.4
900	125.7	0.7
1000	126.4	0
1100	127	-0.5
1200	127.8	-1.4
1300	128.7	-2.2
1400	129.4	-3
1500	130.1	-3.6
1600	130.7	-4.3
1700	131.3	-4.9
1800	131.8	-5.4
1900	132.4	-5.9
2000	132.8	-6.4

Table 44. Expected output for EDUCT for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
10	142.8	3.6
20	147.5	-1.1
30	150.1	-3.6
40	152.5	-6.1
50	156	-9.6
60	158.6	-12.2
70	154.1	-7.7
80	149.5	-3
90	146.3	0.1
100	144.3	2.2
110	143.1	3.4
120	142.7	3.7
130	143.2	3.2
140	145.1	1.3
150	149.4	-3
160	162.2	-15.8
170	151.8	-5.4
180	145.2	1.3
190	142.4	4.1
200	141.5	4.9

Table 45. Expected output for EDUCTRF for r_{max} receiver range of 100 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
10	155	-2.5
20	158.2	-5.7
30	160	-7.6
40	160.7	-8.2
50	161	-8.6
60	161.3	-8.8
70	161.4	-8.9
80	161.5	-9
90	161.5	-9.1
100	161.6	-9.2
110	161.7	-9.2
120	161.7	-9.3
130	161.8	-9.4
140	161.8	-9.4
150	162	-9.5
160	162.1	-9.6
170	162.1	-9.7
180	162.3	-9.8
190	162.4	-9.9
200	162.6	-10.1

Table 46. Expected output for FLTA50 for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
0	-3276.6	-3276.6
5	-3276.6	-3276.6
10	190.3	-63.9
15	159	-32.5
20	152.7	-26.3
25	148.9	-22.5
30	146.1	-19.7
35	143.8	-17.3
40	141.8	-15.3
45	140	-13.6
50	138.4	-12
55	137	-10.5
60	135.6	-9.2
65	134.4	-8
70	133.3	-6.8
75	132.2	-5.8
80	131.2	-4.7
85	130.2	-3.8
90	129.4	-2.9
95	128.5	-2.1
100	127.8	-1.3

Table 47. Expected output for GASABS for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
10	212.7	-60.2
20	199.2	-46.8
30	188.9	-36.5
40	180.1	-27.6
50	172.2	-19.8
60	165.5	-13
70	160.1	-7.6
80	156.7	-4.2
90	156.5	-4
100	163.1	-10.7
110	159.3	-6.9
120	156	-3.6
130	167.8	-15.3
140	155.7	-3.3
150	163	-10.5
160	156.1	-3.6
170	161.9	-9.4
180	155.7	-3.3
190	164.4	-12
200	154.9	-2.5

Table 48. Expected output for GAUSS for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
100	133.7	-7.2
200	123.5	2.9
300	121.7	4.8
400	130.7	-4.3
500	127.1	-0.6
600	124	2.4
700	133	-6.6
800	132.2	-5.7
900	129.6	-3.2
1000	139	-12.6
1100	140	-13.5
1200	138.1	-11.7
1300	148.3	-21.9
1400	150.4	-23.9
1500	149.5	-23.1
1600	160.5	-34.1
1700	163.6	-37.1
1800	163.7	-37.3
1900	175.5	-49.1
2000	179.6	-53.1

Table 49. Expected output for HEIGHT_RTG for receiver height of 500 m.

Range (km)	Prop. Loss (dB)	Prop. Factor (dB)
0.92	-3276.7	-3276.7
1.84	-3276.7	-3276.7
2.76	-3276.7	-3276.7
3.68	-3276.7	-3276.7
4.6	89.6	0.3
5.52	94.3	-2.8
6.44	94.1	-1.2
7.36	93.4	0.6
8.28	92.2	2.8
9.21	94.4	1.5
10.13	94.5	2.3
11.05	93.6	4
11.97	99.8	-1.5
12.89	96.5	2.4
13.81	103.9	-4.5
14.73	97.7	2.4
15.65	97.4	3.1
16.57	99.5	1.6
17.49	105.1	-3.6
18.41	100	1.9

Table 50. Expected output for HF10TER for receiver heights of 0, 1000, and 2000 m.

	Rec. height at 0 m		Rec. height at 1000 m		Rec. height at 2000 m	
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)
8.3	65.5	5.4	66.9	3.9	70.8	0
16.6	71.6	5.3	72.6	4.3	73	3.9
24.9	75.2	5.2	76.2	4.1	76.1	4.3
33.2	77.8	5.1	79.4	3.5	78.7	4.1
41.5	80	4.8	82.2	2.6	80.8	4.1
49.8	81.9	4.5	84.6	1.8	82.6	3.8
58.1	83.6	4.1	86.8	0.9	84.3	3.4
66.4	85.2	3.7	88.9	0	85.8	3
74.7	86.7	3.2	90.8	-0.9	87.2	2.7
83	110.9	-20.1	92.7	-1.9	88.4	2.4
91.3	118.4	-26.8	93	-1.3	90.1	1.6
99.6	122.8	-30.4	94.6	-2.2	89.9	2.5
107.9	-3276.6	-3276.6	93.1	0	91.1	2
116.2	-3276.6	-3276.6	94.6	-0.9	93.4	0.4
124.5	-3276.6	-3276.6	96.8	-2.5	95.4	-1.1
132.8	-3276.6	-3276.6	98.5	-3.6	93.6	1.3
141.1	-3276.6	-3276.6	100.8	-5.3	93.8	1.7
149.4	-3276.6	-3276.6	103.2	-7.3	94.8	1.1
157.7	-3276.6	-3276.6	106.6	-10.2	96.8	-0.4
166	-3276.6	-3276.6	106.2	-9.3	98.6	-1.7
174.3	-3276.6	-3276.6	109.2	-12	100.8	-3.5
182.6	-3276.6	-3276.6	111.1	-13.5	103.1	-5.4
190.9	-3276.6	-3276.6	-3276.6	-3276.6	103	-5
199.2	-3276.6	-3276.6	138.5	-40	104	-5.6
207.5	-3276.6	-3276.6	131.3	-32.5	110.6	-11.9
215.8	-3276.6	-3276.6	129.1	-30	115.9	-16.7
224.1	-3276.6	-3276.6	128.2	-28.7	119.9	-20.4
232.4	-3276.6	-3276.6	-3276.6	-3276.6	121.4	-21.7
240.7	-3276.6	-3276.6	-3276.6	-3276.6	124	-23.9
249	-3276.6	-3276.6	152.1	-51.7	125.8	-25.4

Table 51. Expected output for HF20QWVD for r_{max} receiver range of 100 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
0	114.9	-16.4
50	117	-18.5
100	118.6	-20.1
150	118.8	-20.3
200	117.6	-19.1
250	115.8	-17.3
300	114.1	-15.6
350	112.6	-14.2
400	111.4	-12.9
450	110.4	-11.9
500	109.5	-11
550	108.8	-10.3
600	108.2	-9.8
650	107.8	-9.3
700	107.4	-8.9
750	107.1	-8.6
800	106.8	-8.3
850	106.6	-8.1
900	106.4	-7.9
950	106.1	-7.7
1000	105.9	-7.4

Table 52 Expected output for HF20RF for r_{max} receiver range of 100 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
0	119.8	-21.3
50	122.6	-24.1
100	123.5	-25
150	121.7	-23.3
200	119.3	-20.8
250	117.1	-18.7
300	115.4	-16.9
350	113.9	-15.5
400	112.7	-14.3
450	111.7	-13.2
500	110.9	-12.4
550	110.2	-11.7
600	109.6	-11.1
650	109.1	-10.6
700	108.7	-10.2
750	108.4	-9.9
800	108.1	-9.7
850	107.9	-9.5
900	107.8	-9.3
950	107.6	-9.1
1000	107.4	-9

Table 53. Expected output for HF30 for r_{max} receiver range of 100 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
0	128.9	-26.9
50	131.9	-29.9
100	131.1	-29.1
150	128.2	-26.2
200	125.6	-23.6
250	123.4	-21.5
300	121.7	-19.7
350	120.2	-18.2
400	118.9	-16.9
450	117.7	-15.7
500	116.6	-14.6
550	115.6	-13.7
600	114.8	-12.8
650	113.9	-11.9
700	113.2	-11.2
750	112.5	-10.5
800	111.8	-9.8
850	111.2	-9.2
900	110.6	-8.6
950	110.1	-8.1
1000	109.6	-7.6

Table 54. Expected output for HIBW for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
100	133.6	-7.2
200	123.3	3.1
300	121.1	5.3
400	129.7	-3.3
500	124.9	1.5
600	120.6	5.8
700	128.1	-1.7
800	125.3	1.1
900	120.5	5.9
1000	127.6	-1.1
1100	125.6	0.8
1200	120.5	6
1300	127.5	-1.1
1400	125.6	0.8
1500	120.5	6
1600	127.5	-1
1700	125.6	0.8
1800	120.5	5.9
1900	127.4	-1
2000	125.7	0.8

Table 55. Expected output for HIEL for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
1000	376.4	-250
2000	376.4	-250
3000	376.4	-250
4000	376.4	-250
5000	364.2	-237.7
6000	258.9	-132.4
7000	184.7	-58.1
8000	140.8	-14.2
9000	126.6	0
10000	141.2	-14.6
11000	183.7	-57.1
12000	253.1	-126.4
13000	348.2	-221.5
14000	376.7	-250
15000	376.8	-250
16000	376.8	-250
17000	376.9	-250
18000	376.9	-250
19000	377	-250
20000	377.1	-250

Table 56. Expected output for HIFREQ for r_{max} receiver range of 50 km.

Height (km)	Prop. Loss (dB)	Prop. Factor (dB)
10	205.4	-52.9
20	192	-39.5
30	181.6	-29.2
40	172.8	-20.3
50	164.9	-12.5
60	158.2	-5.7
70	152.8	-0.3
80	149.4	3
90	149.2	3.3
100	155.9	-3.4
110	152	0.4
120	148.7	3.7
130	160.5	-8
140	148.4	4
150	155.7	-3.2
160	148.8	3.7
170	154.6	-2.1
180	148.4	4
190	157.2	-4.7
200	147.6	4.8

Table 57. Expected output for HITRAN for r_{max} receiver range of 50 km.

Height (m)	Prop. Loss (dB)	Prop. Factor (dB)
50	126.3	0.1
100	121.8	4.7
150	138.1	-11.7
200	121.4	5
250	134.6	-8.2
300	122	4.4
350	124.4	2
400	127.7	-1.3
450	120.9	5.5
500	131.4	-5
550	123.2	3.3
600	121.5	5
650	147.9	-21.5
700	121.7	4.7
750	122.3	4.1
800	137.7	-11.3
850	121.1	5.3
900	123.2	3.2
950	132.5	-6.1
1000	120.8	5.6

Table 58. Expected output for HORZ for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
100	133.6	-7.2
200	123.3	3.1
300	121.1	5.3
400	129.7	-3.3
500	124.9	1.5
600	120.6	5.8
700	128.1	-1.7
800	125.3	1.1
900	120.5	5.9
1000	127.6	-1.1
1100	125.6	0.9
1200	120.5	6
1300	127.5	-1
1400	125.6	0.8
1500	120.5	6
1600	127.4	-1
1700	125.6	0.8
1800	120.5	6
1900	127.4	-1
2000	125.6	0.8

Table 59. Expected output for HTFIND for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
100	133.6	-7.2
200	123.4	3
300	121.5	4.9
400	130	-3.6
500	125.8	0.7
600	122.1	4.3
700	128.8	-2.3
800	126.9	-0.5
900	124.4	2
1000	127.1	-0.7
1100	126.5	-0.1
1200	126.4	0
1300	126.4	0
1400	126.4	0
1500	126.4	0
1600	126.4	0
1700	126.4	0
1800	126.4	0
1900	126.4	0
2000	126.4	0

Table 60. Expected output for LOBW for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
100	133.8	-7.4
200	124	2.4
300	123.2	3.2
400	132.9	-6.4
500	133	-6.6
600	134.1	-7.7
700	146.4	-19.9
800	151.8	-25.3
900	156.6	-30.2
1000	171.5	-45.1
1100	181.5	-55.1
1200	190.5	-64
1300	208.4	-81.9
1400	222.4	-96
1500	235.6	-109.2
1600	256.6	-130.1
1700	274.6	-148.2
1800	292	-165.6
1900	316.2	-189.7
2000	338.1	-211.7

Table 61. Expected output for LOEL for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
1000	376.4	-250
2000	376.4	-250
3000	376.4	-250
4000	376.4	-250
5000	358.3	-231.8
6000	254.6	-128.2
7000	181.9	-55.4
8000	139.6	-13.1
9000	126.9	-0.3
10000	142.9	-16.3
11000	186.8	-60.2
12000	257.6	-130.9
13000	354	-227.3
14000	376.7	-250
15000	376.8	-250
16000	376.8	-250
17000	376.9	-250
18000	376.9	-250
19000	377	-250
20000	377.1	-250

Table 62. Expected output for LOFREQ for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
250	116.7	-10.3
500	109	-2.6
750	105	1.4
1000	102.6	3.8
1250	101.2	5.2
1500	100.5	5.9
1750	100.5	5.9
2000	101	5.4
2250	102.3	4.1
2500	104.5	1.9
2750	108.4	-1.9
3000	116.9	-10.5
3250	119.4	-13
3500	109.2	-2.7
3750	104.9	1.5
4000	102.6	3.9
4250	101.2	5.2
4500	100.6	5.9
4750	100.5	6
5000	101	5.5

Table 63. Expected output for LOTRAN for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
500	133.8	-7.3
1000	126.3	0.2
1500	122.9	3.5
2000	121.2	5.3
2500	120.5	6
3000	120.7	5.8
3500	121.8	4.6
4000	124.1	2.3
4500	128.5	-2
5000	140.4	-14
5500	134.2	-7.7
6000	126.7	-0.2
6500	123.2	3.3
7000	121.4	5.1
7500	120.7	5.8
8000	120.8	5.8
8500	121.7	4.9
9000	123.6	3
9500	127.1	-0.6
10000	134.8	-8.2

Table 64. Expected output for MPRT for receiver heights of 0 and 1100 m.

	Rec. height at 0 m		Rec. height at 1100 m	
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)
2	369.9	-281.9	348.1	-260
4	377.6	-283.6	361.7	-267.6
6	389.7	-292.2	376.8	-279.2
8	374.3	-274.3	357.8	-257.7
10	274.5	-172.5	365.6	-263.6
12	-3276.6	-3276.6	313.5	-209.9
14	-3276.6	-3276.6	265.1	-160.2
16	-3276.6	-3276.6	261.7	-155.6
18	-3276.6	-3276.6	265.6	-158.5
20	-3276.6	-3276.6	206.2	-98.2
22	-3276.6	-3276.6	149	-40.1
24	-3276.6	-3276.6	123.4	-13.8
26	-3276.6	-3276.6	121.9	-11.6
28	-3276.6	-3276.6	134.8	-23.9
30	-3276.6	-3276.6	156.8	-45.2
32	-3276.6	-3276.6	181	-68.9
34	-3276.6	-3276.6	207.2	-94.6
36	-3276.6	-3276.6	233.8	-120.6
38	-3276.6	-3276.6	244	-130.4
40	-3276.6	-3276.6	245.4	-131.4
42	-3276.6	-3276.6	246.8	-132.3
44	-3276.6	-3276.6	249	-134.1
46	-3276.6	-3276.6	252.2	-136.9
48	-3276.6	-3276.6	256.8	-141.1
50	316.7	-200.7	261.6	-145.7
52	327.9	-211.6	267	-150.7
54	322.1	-205.5	271.8	-155.2
56	321.3	-204.3	275.8	-158.9
58	320.1	-202.8	279.4	-162.1
60	319.7	-202.2	282.1	-164.5

Table 65. Expected output for PERW for receiver heights of 0 and 1000 m.

	Rec. height at 0 m		Rec. height at 1100 m	
Range (km)	Prop. Loss (dB)	Prop. Factor (dB)	Prop. Loss (dB)	Prop. Factor (dB)
2.5	122.7	-32.8	179.8	-89.9
5	135	-39	129.6	-33.6
7.5	142.3	-42.8	95.9	3.6
10	147.7	-45.7	110.7	-8.7
12.5	152	-48.1	99.7	4.2
15	155.7	-50.2	102.4	3.1
17.5	158.9	-52.1	110.2	-3.3
20	-3276.6	-3276.6	119.7	-11.6
22.5	-3276.6	-3276.6	111.8	-2.8
25	-3276.6	-3276.6	108.7	1.2
27.5	-3276.6	-3276.6	108.1	2.7
30	-3276.6	-3276.6	106.9	4.6
32.5	-3276.6	-3276.6	107.6	4.6
35	196.5	-83.6	109	3.8
37.5	191	-77.5	109.3	4.2
40	187.8	-73.8	110.3	3.8
42.5	186.1	-71.5	109.8	4.7
45	185.2	-70.1	109.5	5.6
47.5	184.8	-69.3	109.1	6.4
50	184.8	-68.8	111.9	4.1

Table 66. Expected output for PVT for r_{max} receiver range of 10 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
0	-3276.6	-3276.6
100	-3276.6	-3276.6
200	-3276.6	-3276.6
300	101.3	5.1
400	113.6	-7.1
500	103.9	2.6
600	105.2	1.2
700	109.5	-3
800	104.1	2.3
900	107	-0.5
1000	107.7	-1.3
1100	106.2	0.3
1200	105.8	0.7
1300	102.9	3.6
1400	108.5	-2.1
1500	104.1	2.3
1600	107.5	-1.1
1700	103.3	3.1
1800	104.7	1.7
1900	111	-4.6
2000	104	2.4

Table 67. Expected output for RDLONGB for r_{max} receiver range of 100 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
50	138.7	-22.8
100	133.1	-17.1
150	129.3	-13.3
200	126.4	-10.5
250	126.8	-10.8
300	129.5	-13.5
350	125	-9.1
400	121.7	-5.7
450	119.1	-3.2
500	118.5	-2.5
550	118.5	-2.5
600	117.1	-1.1
650	114.6	1.4
700	112.6	3.4
750	113.6	2.4
800	112.6	3.4
850	111	5
900	110.9	5.1
950	110.9	5.1
1000	110.1	5.8

Table 68. Expected output for RNGDEP for r_{max} receiver range of 250 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
100	199.8	-49.9
200	195.8	-45.9
300	202.8	-52.8
400	178.6	-28.7
500	141.9	8
600	135.4	14.5
700	150.9	-0.9
800	164.2	-14.2
900	166.8	-16.9
1000	182.9	-33
1100	196.7	-46.8
1200	197.4	-47.4
1300	200.7	-50.8
1400	195.1	-45.2
1500	192.9	-43
1600	191.5	-41.5
1700	192.4	-42.4
1800	195.5	-45.5
1900	194.5	-44.6
2000	193.3	-43.3

Table 69. Expected output for SBDUCT for r_{max} receiver range of 200 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
250	139.9	8.1
500	166	-18
750	157	-9
1000	161.3	-13.3
1250	174.6	-26.6
1500	169.5	-21.4
1750	158.6	-10.6
2000	150.8	-2.8
2250	146.9	1.1
2500	147.7	0.3
2750	165.7	-17.7
3000	145.1	3
3250	148	0
3500	147	1
3750	145.3	2.7
4000	149.7	-1.7
4250	144.4	3.7
4500	149.9	-1.9
4750	144.5	3.5
5000	148	0

Table 70. Expected output for SBDUCTRF for r_{max} receiver range of 200 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
0	182.2	-34.2
50	141.7	6.3
100	136.5	11.5
150	141.5	6.5
200	141.5	6.5
250	141	7
300	152.5	-4.4
350	171.6	-23.6
400	182.7	-34.7
450	173	-25
500	169.4	-21.4
550	165.7	-17.7
600	163.3	-15.3
650	160.9	-12.9
700	159.9	-11.9
750	159.2	-11.1
800	159.2	-11.2
850	159.4	-11.4
900	160.1	-12
950	161.2	-13.1
1000	162.5	-14.5

Table 71. Expected output for SINEX for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
100	133.7	-7.2
200	123.5	3
300	121.6	4.8
400	130.7	-4.3
500	127	-0.6
600	124.1	2.4
700	133.3	-6.8
800	133	-6.6
900	131.9	-5.4
1000	143.2	-16.8
1100	151.3	-24.8
1200	150.9	-24.5
1300	157.9	-31.5
1400	156.1	-29.6
1500	150.9	-24.5
1600	157.9	-31.5
1700	156.1	-29.7
1800	150.9	-24.5
1900	157.9	-31.5
2000	156.1	-29.7

Table 72. Expected output for TROPOS for r_{max} receiver range of 200 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
100	165.2	-46.7
200	164.6	-46.1
300	164.5	-46
400	164.4	-46
500	164.4	-46
600	164.2	-45.7
700	163.4	-45
800	162.1	-43.6
900	160.2	-41.8
1000	158	-39.6
1100	155.7	-37.2
1200	153.4	-34.9
1300	151.2	-32.7
1400	149	-30.5
1500	146.9	-28.4
1600	144.9	-26.5
1700	143.1	-24.6
1800	141.3	-22.8
1900	139.6	-21.1
2000	138	-19.6

Table 73. Expected output for TROPOT for r_{max} receiver range of 200 km..

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
100	164.8	-46.3
200	163.8	-45.3
300	162.8	-44.3
400	161.2	-42.7
500	159.2	-40.7
600	157	-38.6
700	155.1	-36.6
800	153.5	-35.1
900	152.4	-33.9
1000	151.6	-33.2
1100	151.2	-32.7
1200	150.6	-32.2
1300	149.6	-31.1
1400	147.9	-29.4
1500	145.9	-27.4
1600	143.9	-25.4
1700	142.1	-23.7
1800	140.6	-22.2
1900	139.1	-20.6
2000	137.4	-18.9

Table 74. Expected output for USERDEFA for r_{max} receiver range of 300 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
150	137.7	3.3
300	138.8	2.3
450	159	-17.9
600	153.2	-12.2
750	151.3	-10.2
900	152.6	-11.5
1050	154.8	-13.8
1200	158.9	-17.9
1350	168.6	-27.5
1500	165	-24
1650	156.5	-15.4
1800	153.6	-12.5
1950	153	-11.9
2100	152.2	-11.1
2250	151	-10
2400	151	-10
2550	151.8	-10.7
2700	152.5	-11.4
2850	153.7	-12.6
3000	155.3	-14.2

Table 75. Expected output for USERHF for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
100	133.6	-7.2
200	123.8	2.6
300	122.6	3.8
400	128.9	-2.5
500	126.7	-0.3
600	126	0.4
700	126.4	0
800	126.4	0
900	126.4	0
1000	126.4	0
1100	127.3	-0.9
1200	127.3	-0.9
1300	127.3	-0.9
1400	127.3	-0.9
1500	128.4	-1.9
1600	128.4	-1.9
1700	128.4	-1.9
1800	128.4	-1.9
1900	128.4	-1.9
2000	129.5	-3.1

Table 76. Expected output for VERT for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
0	186.9	-60.5
100	133.8	-7.3
200	123.5	2.9
300	121.4	5.1
400	129.3	-2.9
500	125.9	0.5
600	121.3	5.1
700	127.8	-1.4
800	127	-0.6
900	121.7	4.8
1000	127.2	-0.8
1100	127.9	-1.5
1200	122.1	4.4
1300	126.9	-0.5
1400	128.5	-2
1500	122.5	4
1600	126.7	-0.3
1700	128.8	-2.4
1800	122.8	3.6
1900	126.5	-0.1
2000	129.1	-2.7

Table 77. Expected output for VERTMIX for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
0	150.7	-44.3
50	141.8	-35.4
100	134.7	-28.3
150	130.4	-24
200	127.2	-20.8
250	124.6	-18.2
300	122.4	-16
350	120.5	-14.1
400	118.9	-12.5
450	117.6	-11.1
500	116.4	-10
550	115.4	-9
600	114.5	-8.1
650	113.7	-7.3
700	113.3	-6.9
750	112.6	-6.2
800	112	-5.6
850	111.4	-5
900	110.8	-4.4
950	110.3	-3.9
1000	109.8	-3.4

Table 78. Expected output for VERTSEA for r_{max} receiver range of 300 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
0	145.6	-23.6
50	136.4	-14.4
100	129.9	-7.9
150	127.1	-5.1
200	126.7	-4.7
250	129.2	-7.2
300	135.9	-13.9
350	143.8	-21.8
400	147.6	-25.7
450	146.3	-24.3
500	144.9	-22.9
550	144.2	-22.3
600	144	-22
650	144	-22
700	144.2	-22.2
750	144.6	-22.6
800	145	-23
850	145.5	-23.5
900	145.9	-23.9
950	146.3	-24.3
1000	146.6	-24.6

Table 79. Expected output for VERTUSRD for r_{max} receiver range of 50 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
0	174.6	-68.2
50	140.5	-34.1
100	134	-27.5
150	129.8	-23.4
200	126.8	-20.3
250	124.3	-17.9
300	122.2	-15.8
350	120.5	-14.1
400	119	-12.5
450	117.7	-11.2
500	116.5	-10.1
550	115.4	-9
600	114.5	-8.1
650	113.7	-7.2
700	113.3	-6.9
750	112.6	-6.2
800	112	-5.6
850	111.4	-5
900	110.8	-4.4
950	110.3	-3.9
1000	109.8	-3.4

Table 80. Expected output for WEDGE for r_{max} receiver range of 100 km.

Height (meters)	Prop. Loss (dB)	Prop. Factor (dB)
50	154.5	-22
100	154.7	-22.3
150	155.7	-23.3
200	155.5	-23
250	154	-21.6
300	152.1	-19.7
350	150.3	-17.9
400	149	-16.6
450	148.1	-15.6
500	146.8	-14.4
550	144	-11.5
600	139.7	-7.3
650	135.4	-2.9
700	131.6	0.9
750	128.3	4.1
800	126.3	6.2
850	126.9	5.6
900	127.8	4.6
950	127.4	5
1000	130.2	2.2
50	154.5	-22

4.5 CRITERIA FOR EVALUATING RESULTS

The calculated propagation loss in dB should match the numerical values in each table at each of the levels shown to within 0.1 dB (1 cB). APM rounds its output loss values to the nearest 1 cB, and hence it is possible for differences of 1 cB to exist between different implementations of APM. It is expected, however, that in most cases the values will match those inTable 33 through Table 80 exactly.

4.6 TEST PROCEDURE

1. Compile for execution, the APM CSCI, the driver program APMMAIN.F90, and the module APM_MOD.F90.

2. An input data file has been provided, as a text file, for each test case.

3. The APM CSCI is executed in a form that reads the input data file, performs the calculations, and writes the output to a text file.

4. The output file is compared to the final expected test results to determine satisfactory performance.

4.7 ASSUMPTIONS AND CONSTRAINTS

Input data elements are assumed to be constrained by the limits listed within Tables 1 through 4 of the Software Requirements Specification (Ref. 3).

5. REQUIREMENTS TRACEABILITY

The provided driver program that accesses the APM CSCI will create an output file for each test case. The output file will have the same prefix name as the input file. The extension is ".OUT". This output file contains height in meters and corresponding propagation loss in dB that should correspond to the entries in Table 33 through Table 80 for each test case.

The provided program APMMAIN.FOR, when compiled with the APM CSCI, will read the provided input files containing all necessary information for each test case. Each input file is named for each test case, with a ".IN" extension.

6. NOTES

Table 81 is a glossary of acronyms and abbreviations used within this document.

Table 81. Acronyms and Abbreviations.

Term	Definition
abs_{hum}	Surface absolute humidity (g/m^3)
ant_{gain}	Antenna gain (dBi)
ant_{ht}	Antenna height
APM	Advanced Propagation Model
cB	centibel
C_{lut}	Logical flag used to indicate if surface clutter calculations are desired
CSC	Computer Software Component
CSCI	Computer Software Configuration Item
dB	Decibel
dielec	2-dimensional array of relative permittivity and conductivity
EM	Electromagnetic
FORTRAN	Formula Translation
f_{MHz}	EM system frequency (MHz)
γ_a	Surface specific attenuation rate (dB/km)
γ_c	Array of "backscattering effectiveness" term used in reflectivity computation (dB)
γrng	Array of corresponding ranges for γ_c (km)
hfang	User-defined height-finder power reduction angle array (deg)
hffac	User-defined power reduction factor array
h_{max}	Maximum height output for a particularapplication of APM.
h_{min}	Minimum height output for a particular application of APM.
hmsl	Refractivity profile height array
i_{extra}	Extrapolation flag for refractivity profiles entered below mean sea level
i_{gc}	Number of γ_c values and corresponding ranges
i_{gr}	Number of ground composition types for particular application of APM
igrnd	Ground composition type array
i_{pat}	Antenna pattern
i_{pol}	Antenna polarization
lang	Logical flag indicating if propagation angle and propagation factor output for specific ray paths is desired
lerr6	Controlling logical flag for error 6
lerr12	Controlling logical flag for error 12

Table 81. Acronyms and Abbreviations. (Continued)

Term	Definition
L_{sys}	System loss (dB)
$lvlp$	Number of levels in refractivity profiles for particular application of APM
km	kilometers
m	meters
N/A	Not applicable
N_f	Noise figure (dB)
n_{facs}	Number of power reduction factors and cut-back angles for user-defined height finder radar
n_{prof}	Number of refractivity profiles for particular application of APM
n_{rout}	Number of range output points for a particular application of APM.
n_w	Number of wind speeds
n_{zout}	Number of height output points for a particular application of APM.
n_{zout_rtg}	Number of height output points relative to ground for a particular application of APM.
PE_{flag}	Logical flag indicating PE-only mode
P_t	Transmitter power (kW)
$refmsl$	Refractivity profile M-unit array
$rgrnd$	Gound composition type range array
r_{max}	Maximum range output for a particular application of APM.
r_{mult}	PE range step multiplier
$rngprof$	Refractivity profile range array
$rngwind$	Range array of wind speeds
t_{air}	Surface air temperature (°C)
τ	Pulse width/length (microseconds)
$terx$	Terrain profile range array
$tery$	Terrain profile height array
θ_{hbw}	Antenna horizontal beam width (degrees)
th_{max}	Visible portion of maximum PE propagation angle
T_{ropo}	Logical flag to include troposcatter calculations
μ_{bw}	Antenna vertical beam width (degrees)
μ_o	antenna elevation angle (degrees)
$wind$	Wind speed array (m/s)
$wind_{dir}$	Wind direction relative to boresight (degrees)
$zout\_rtg$	Array of receiver heights relative to local surface elevation (m)

7. SAMPLE PROGRAM LISTING

The sample driver program APMMAIN.F90, which exercises the APM CSCI, is provided below.

```
!************** APMMAIN DRIVER PROGRAM FOR APM Ver 2.1.04 ***************

! This is a sample driver program for APM routines APMINIT, APMSTEP,
! RET_GRAZE, XOINIT, and XOSTEP.  All numeric parameters passed to
! APMINIT and APMSTEP must be in metric units.  All input arrays are
! dynamically allocated and are dimensioned with variable sizes.

! This program reads an input (normally designated as a ".IN" file)
! and generates a ".OUT" file.  Depending on the input parameters,
! there will be additional output files generated:

! 1) If the propagation loss relative to the ground height is desired
!    and the appropriate input parameters have been specified, then a
!    file ".RTG" will be generated.

! 2) If clutter-to-noise is desired and the appropriate parameters have
!    been specified, then a file ".CNR" will be generated.

! 3) If propagation angles and factors for direct/reflected rays are
!    desired, then a file ".AF" will be generated.

program apmmain

implicit integer(kind=4) (i-n)
implicit real(kind=8) (a-h, o-z)

character filein*50, fileall*50, answer*1

external apmstatus

data inf, iall / 14, 16 /

10 continue

write(*,'(a\)')' Name of input file? '
read(*, '(a)' ) filein

! If the filename has a ".IN" extension then this is a one-time
! APM run.

ichk = index( filein, '.in' )
if( ichk .gt. 0 ) then

!This just opens, reads, and runs one APM case at a time.

   call runapm( inf, filein )

else

! This assumes all input filenames (*.IN) are contained in a text file
! withOUT extension .IN. This runs all input files (filenames
! contained in FILEALL) in one 'batch' run.

   fileall = filein
   open( iall, file = fileall )
   do while( .not. eof( iall ) )
      read( iall, '(a)', err=20, end=20 ) filein
```

```
      call runapm( inf, filein )
   end do

20 continue

end if

write(*,'(a\)')' Input another file? (y or n)'
read(*, '(a)' ) answer
if(( answer .eq. 'y' ) .or. ( answer .eq. 'Y')) goto 10

end

!*************************** SUBROUTINE RUNAPM ******************************

subroutine runapm( inf, filein )

use apm_mod

implicit integer(kind=4) (i-n)
implicit real(kind=8) (a-h, o-z)

!MPFL must be declared an INTEGER*2 allocatable array.
!ITLOSS is a dummy array and will be used to store entire loss grid.
!ITPFAC is a dummy array and will be used to store entire propagation factor
grid.

!NOTE: Propagation factor is output as 20*LOG10(F).

integer(kind=2), allocatable :: mpfl(:,:), itloss(:,:), itpfac(:,:),
mpfl_rtg(:,:)
real( kind=8 ), allocatable :: angfac(:,:,:), cnr_dB(:), graze_at_rout(:),
propaf(:,:)
logical( kind = 4 ) lgraze

character filein*(*)

external apmstatus

data ioutf, ioutrtg, ioutcnr, ioutaf / 15, 40, 41, 42 /

open( inf, file=filein )

lmsl = .true.  !For now hard-wire this parameter to "True"

!*********************************READ CALC INFO******************************

read( inf, * ) lerr6
read( inf, * ) lerr12

read( inf, * ) peflag  !Perform field calcs using PE model only?
read( inf, * ) thmax   !Maximum PE calculation angle in degrees (used only if
                       ! PEFLAG = .true.
read( inf, * ) rmult   !PE range step multiplier (used only if PEFLAG = .true.)
read( inf, * ) tropo   !Troposcatter flag: .false.=no troposcatter,
.true.=troposcatter

!Clutter flag: Logical variable
!   If .True. = perform clutter calculations
!   If .False. = no clutter calculations are performed

read( inf, * ) clut

!Propagation angle/factor flag: Logical variable
!   If .True. = compute propagation angles and factors for direct and
!               reflected rays (where applicable).  These values will be
```

```fortran
!               passed back through array PROPAF in calls to APMSTEP
!               and XOSTEP.
!   If .False. = no extra computations

read( inf, * ) lang

!********************************READ SYSTEM INFO******************************

read( inf, * ) freq        !Frequency in MHz.
read( inf, * ) antht       !antenna height.
read( inf, * ) ipat        !antenna type
read( inf, * ) ipol        !antenna polarization.

!This value is ignored for Omni antenna, otherwise, the value must be
!entered in degrees.

read( inf, * ) bwidth

!This value is ignored for Omni antenna, otherwise, the value must be
!entered in degrees.

read( inf, * ) elev

!If using specific height-finder antenna, this variable contains a non-zero
!value corresponding to the # of cut-back angles and cut-back factors.

read( inf, * ) nfacs

! If using specific height-finder antenna, then must specify values for HFANG()
and
! HFFAC arrays.  Height-finder cut-back angles HFANG() must be in degrees.

if( nfacs .gt. 0 ) then
   IF( ALLOCATED( hfang ) ) DEALLOCATE( hfang, stat=ierror )
   ALLOCATE( hfang(nfacs), stat=ierror )
   if( ierror .ne. 0 ) then
      write(*,*)'**********ERROR IN HFANG ALLOCATION***********'
      stop
   end if
   hfang = 0.

   IF( ALLOCATED( hffac ) ) DEALLOCATE( hffac, stat=ierror )
   ALLOCATE( hffac(nfacs), stat=ierror )
   if( ierror .ne. 0 ) then
      write(*,*)'**********ERROR IN HFFAC ALLOCATION***********'
      stop
   end if
   hffac = 0.

   do i = 1, nfacs
      read( inf, * ) hfang(i), hffac(i)
   end do
end if

!If performing clutter calculations then the following parameters MUST
!be specified

read( inf, * ) antgain  !Antenna gain in dBi
read( inf, * ) horbw    !Horizontal beamwidth in deg
read( inf, * ) puls_len !Pulse length in microseconds
read( inf, * ) tx_pow   !Transmitter power in kW
read( inf, * ) sysloss  !System losses in dB
read( inf, * ) qnoisef  !Noise figure in dB

!***************************READ GENERIC INPUT INFO****************************
```

```
read( inf, * ) hmin          !Minimum height in m
read( inf, * ) hmax          !Maximum output height in m
read( inf, * ) rkm           !Maximum output range in km
rmax = rkm * 1.d3           !Convert to m and initialize RMAX for input to APM.
read( inf, * ) nzout         !Number of output height points.
read( inf, * ) nrout         !Number of output range points.

!Allocate and initialize array for loss computation relative to ground.

read( inf, * ) nzout_rtg         !Number of output height points relative to
ground.
if( nzout_rtg .gt. 0 ) then
   if( allocated( zout_rtg ) ) deallocate( zout_rtg, stat=ierror )
   allocate( zout_rtg(nzout_rtg), stat=ierror )
   if( ierror .ne. 0 ) then
      write(*,*)'********ERROR IN ZOUT_RTG ALLOCATION********'
      stop
   end if
   zout_rtg = 0.

!Now read all receiver heights in meters relative to ground.

   do i = 1, nzout_rtg
      read( inf, * ) zout_rtg(i)
   end do
end if

!Allocate MPFL_RTG() - will occur regardless of value of NZOUT_RTG.

if( allocated( mpfl_rtg ) ) deallocate( mpfl_rtg, stat=ierror )
allocate( mpfl_rtg(2,nzout_rtg), stat=ierror )
if( ierror .ne. 0 ) stop
mpfl_rtg = -32767

!****************************READ METEOROLOGICAL
INFO*****************************

read( inf, * ) iextra        !Extrapolation flag:
                               !0=extrapolate using standard gradient,
                               !1=extrapolate using gradient from first 2 levels.
read( inf, * ) abshum        !Surface absolute humidity in g/m**3
read( inf, * ) tair          !Surface air temperature in degrees C
read( inf, * ) gammaa        !Gaseous absorption attenuation rate in dB/km

read( inf, * ) nw            !Number of wind speeds specified.

if( nw .gt. 0 ) then        !If wind speeds specified, allocate memory.

   IF( ALLOCATED( RNGWIND ) ) DEALLOCATE( RNGWIND )
   ALLOCATE( RNGWIND(NW) )
   RNGWIND = 0.

   IF( ALLOCATED( WIND ) ) DEALLOCATE( WIND )
   ALLOCATE( WIND(NW) )
   WIND = 0.

!Read wind speeds and ranges.

   do i = 1, nw
      read( inf, * ) wind(i), rngwind(i)   !Wind speed in m/s and range in km at
   end do                                 !which to apply specified wind speed.
   rngwind = 1.d3 * rngwind  !Convert RNGWIND from km to m.
end if
```

```
read( inf, * ) nprof       !Number of refractivity profiles
read( inf, * ) lvlp        !Number of levels in refractivity profiles.

! Allocate and initialize height/refractivity and range arrays.

IF( ALLOCATED( HMSL ) ) DEALLOCATE( HMSL, stat=ierror )
ALLOCATE( HMSL(0:LVLP, NPROF), stat=ierror )
if( ierror .ne. 0 ) then
   write(*,*)'**********ERROR IN HMSL ALLOCATION***********'
   stop
end if
HMSL = 0.

IF( ALLOCATED( REFMSL ) ) DEALLOCATE( REFMSL, stat=ierror )
ALLOCATE( REFMSL(0:LVLP, NPROF), stat=ierror )
if( ierror .ne. 0 ) then
   write(*,*)'**********ERROR IN REFMSL ALLOCATION***********'
   stop
end if
REFMSL = 0.

IF( ALLOCATED( RNGPROF ) ) DEALLOCATE( RNGPROF, stat=ierror )
ALLOCATE( RNGPROF(NPROF), stat=ierror )
if( ierror .ne. 0 ) then
   write(*,*)'**********ERROR IN RNGPROF ALLOCATION***********'
   stop
end if
RNGPROF = 0.

do i = 1, nprof
   read( inf, * ) rngp              !Range of profile in km
   rngprof(i) = rngp * 1.d3        !Convert profile range from km to m
   do j = 0, lvlp-1
      read( inf, * ) hmsl(j,i), refmsl(j,i)  !Height/refractivity levels
   end do
end do

read( inf, * ) wind_dir  !Used in clutter calculations.

!********************************READ TERRAIN INFO******************************

read( inf, * ) igr          !Number of ground composition types

if( igr .gt. 0 ) then

   IF( ALLOCATED( DIELEC ) ) DEALLOCATE( DIELEC, stat=ierror )
   ALLOCATE( DIELEC(2, IGR), stat=ierror )
   if( ierror .ne. 0 ) then
      write(*,*)'**********ERROR IN DIELEC ALLOCATION***********'
      stop
   end if
   DIELEC = 0.

   IF( ALLOCATED( IGRND ) ) DEALLOCATE( IGRND, stat=ierror )
   ALLOCATE( IGRND(IGR), stat=ierror )
   if( ierror .ne. 0 ) then
      write(*,*)'**********ERROR IN IGRND ALLOCATION***********'
      stop
   end if
   IGRND = 0.

   IF( ALLOCATED( RGRND ) ) DEALLOCATE( RGRND, stat=ierror )
   ALLOCATE( RGRND(IGR), stat=ierror )
   if( ierror .ne. 0 ) then
```

```
      write(*,*)'**********ERROR IN RGRND ALLOCATION***********'
      stop
   end if
   RGRND = 0.

! Read ranges at which ground types apply, ground composition types, and
dielectric
! constants.  If IGRND(i) = 7, then must specify non-zero values for DIELEC(),
otherwise
! set to 0.  Ranges of ground types are read in km.

   do i = 1, igr
      read( inf, * ) rground, igrnd(i), (dielec(j,i),j=1,2)
      rgrnd(i) = rground * 1.d3
   end do

end if

read( inf, * ) igc   !Number of GAMMAC and GAMRNG pairs - used for clutter
calcs.

if( igc .gt. 0 ) then

   IF( ALLOCATED( GAMMAC ) ) DEALLOCATE( GAMMAC, stat=ierror )
   ALLOCATE( GAMMAC(IGC), stat=ierror )
   if( ierror .ne. 0 ) then
      write(*,*)'**********ERROR IN GAMMAC ALLOCATION***********'
      stop
   end if
   GAMMAC = 0.d0

   IF( ALLOCATED( GAMRNG ) ) DEALLOCATE( GAMRNG, stat=ierror )
   ALLOCATE( GAMRNG(IGC), stat=ierror )
   if( ierror .ne. 0 ) then
      write(*,*)'**********ERROR IN GAMRNG ALLOCATION***********'
      stop
   end if
   GAMRNG = 0.d0

! Read GAMMAC factor and corresponding ranges at which it applies. GAMMAC
describes
! the backscattering effectiveness of the surface and is provided in dB.
! Ranges of ground types are read in km.

   do i = 1, igc
      read( inf, * ) gammac(i), grng
         gamrng(i) = grng * 1.d3
   end do

end if

read( inf, * ) itp           !Number of terrain range/height points
if( itp .gt. 1 ) then ! Valid terrain profile must contain at least two
                      ! height/range points.

   IF( ALLOCATED( TERX ) ) DEALLOCATE( TERX, stat=ierror )
   ALLOCATE( TERX(ITP), stat=ierror )
   if( ierror .ne. 0 ) then
      write(*,*)'**********ERROR IN TERX ALLOCATION***********'
      stop
   end if
   TERX = 0.

   IF( ALLOCATED( TERY ) ) DEALLOCATE( TERY, stat=ierror )
   ALLOCATE( TERY(ITP), stat=ierror )
```

```
   if( ierror .ne. 0 ) then
      write(*,*)'**********ERROR IN TERY ALLOCATION***********'
      stop
   end if
   TERY = 0.

   do i = 1, itp
      read( inf, * ) terrain_x, tery(i)
      terx(i) = terrain_x * 1.d3
   end do

end if
close(inf)

!********************************************************************
!Allocate and initialize all arrays passed through parameter lists.

if( allocated( mpfl ) ) deallocate( mpfl, stat=ierror )
allocate( mpfl(2,0:nzout), stat = ierror )
if( ierror .ne. 0 ) then
   write(*,*)'******ERROR IN MPFL ALLOCATION*******'
   stop
end if
mpfl = 0

if( allocated( propaf ) ) deallocate( propaf, stat=ierror )
allocate( propaf(4,nzout), stat=ierror )
if( ierror .ne. 0 ) then
   write(*,*)'********ERROR IN PROPAF ALLOCATION********'
   stop
end if
propaf = -999.d0
!********************************************************************

!********************************************************************
! These arrays are only necessary to output everything in one big file

if( lang ) then
   if( allocated( angfac ) ) deallocate( angfac, stat = ierror )
   allocate( angfac(4,nzout,nrout), stat=ierror )
   if( ierror .ne. 0 ) then
      write(*,*)'********ERROR IN ANGFAC ALLOCATION********'
      stop
   end if
   angfac = -999.d0
end if

if( allocated( itloss ) ) deallocate( itloss, stat=ierror )
allocate( itloss(0:nzout,nrout), stat=ierror )
if( ierror .ne. 0 ) then
   write(*,*)'******ERROR IN ITLOSS ALLOCATION*******'
   stop
end if
itloss = 0

if( allocated( itpfac ) ) deallocate( itpfac, stat=ierror )
allocate( itpfac(0:nzout,nrout), stat=ierror )
if( ierror .ne. 0 ) then
   write(*,*)'******ERROR IN ITPFAC ALLOCATION*******'
   stop
end if
itpfac = 0

!********************************************************************
```

```
! Allocate and initialize CNR_dB array with proper size

isize_cnr = 1
if( clut ) isize_cnr = nrout
if( allocated( cnr_dB ) ) deallocate( cnr_dB, stat=ierror )
allocate( cnr_dB(isize_cnr), stat=ierror )
if( ierror .ne. 0 ) then
   write(*,*)'********ERROR IN CNR_dB ALLOCATION********'
   stop
end if
cnr_dB = 0.d0

! Write all input parameters that create the resulting output propagation loss
! values as part of the log file.

call write_log( filein, ioutf, IP )

hmin_bef = hmin
hmax_bef = hmax

alimv = 0.d0  ! ***MAKE SURE THIS VARIABLE IS INITIALIZED TO ZERO BEFORE ANY ***
              ! ***CALLS TO APMINIT. THIS IS FOR SPAWAR USE ONLY.****

! Variables in CAPS are returned.

call apminit( IXOSTP, LGRAZE, apmstatus, IERROR )

if( ierror .ne. 0 ) then
   write(*,*)'*********** ERROR IN APMINIT **************'
   write(*,*)'******** IERROR = ', ierror,' **********'
   stop
end if

! After call to APMINIT return grazing angles and do height interpolation on
! propagation angles (if necessary).

ntmp = 1
if( lgraze ) ntmp = nrout
if( allocated( graze_at_rout ) ) deallocate( graze_at_rout, stat=ierror )
allocate( graze_at_rout(ntmp), stat=ierror )
if( ierror .ne. 0 ) then
   write(*,*)'************ERROR IN GRAZE_AT_ROUT ALLOCATION************'
   stop
end if
graze_at_rout = 0.d0

if( lgraze ) call ret_graze( GRAZE_AT_ROUT, IERROR )

! Notify user that HMIN or HMAX has been changed on return from APMINIT.
! The calculation height (HMAX-HMIN) must be at least 100 m.

hmin_aft = hmin
if( dabs(hmin_bef - hmin_aft) .gt. 1.d-3 ) then
   write(ioutf,*)
   write(ioutf,*)' *****************WARNING******************'
   write(ioutf,*)'HMIN has been adjusted to ', hmin, 'meters'
   write(ioutf,*)' ******************************************'
end if

hmax_aft = hmax
if( dabs(hmax_bef - hmax_aft) .gt. 1.d-3 ) then
   write(ioutf,*)
   write(ioutf,*)' *****************WARNING******************'
   write(ioutf,*)'HMAX has been adjusted to ', hmax, 'meters'
   write(ioutf,*)' ******************************************'
```

```
end if

! Create and write header info for extraneous files.

call write_extra( ip, filein, ioutrtg, ioutcnr, ioutaf )

!******************** START OF MAIN APM LOOP **************************

do istp = 1, nrout

! JSTART = start of valid loss points, JEND = end of valid loss
! points.  If at a range where extended optics will be applied, then
! JEND will be the index at top of PE region in MPFL().

   call apmstep( istp, ROUT, MPFL, JSTART, JEND, MPFL_RTG, PROPAF )

   write(*,*)'range in km = ', rout*1.d-3  !Output to screen

! Store loss and propagation factor points in 2-dim. grid for later output to
file.

   itloss( 0:nzout, istp ) = mpfl( 1, 0:nzout )  !prop loss
   itpfac( 0:nzout, istp ) = mpfl( 2, 0:nzout )  !prop factor

!**** Output to separate file for loss relative to ground.******
!*** NOTE: ALL HEIGHTS SPECIFIED FOR LOSS RELATIVE TO GROUND ARE ASSUMED TO BE
AT
!RELATIVELY LOW ALTITUDE - I.E., ALL HEIGHTS ARE CONTAINED WITHIN THE FE, RO, OR
PE
!REGIONS. *******

   if( lrtg ) then
      write( ioutrtg, '((f10.1,5x)\)')rout*1.d-3, (dble(mpfl_rtg(1,i)*.1),
i=1,nzout_rtg )
         write( ioutrtg, * )
   end if

! If necessary move values in PROPAF to larger array ANGFAC for later
! output after calls to XOINIT & XOSTEP.

   if( lang ) angfac(1:4, 1:jend, istp) = propaf(1:4, 1:jend)

end do

if( lrtg ) close(ioutrtg)

! Initialize variables to be used in XO model.

call xoinit( graze_at_rout, ixostp, jend, JXSTART, CNR_dB, IERROR )
if( ierror .gt. 0 ) then
   write(*,*)'*******ERROR IN XOINIT*******'
   stop
end if

! Output height increment DZOUT, as determined in APMINIT, is computed as
! DZOUT = (HMAX-HMIN) / float( NZOUT )

! Output range increment DROUT, as determined in APMINIT, is computed as
! DROUT = RMAX / float( NROUT )

! **** Output to separate file for clutter-to-noise ratio computed in XOINIT
******

if( clut ) then
   do i = 1, nrout
      write( ioutcnr, '(2(f10.1,2x))') drout*real(i,8)*1.d-3, cnr_dB(i)
```

```fortran
   end do
   close( ioutcnr )
end if

! If extended optics model needs to be used, then call.

if( ixostp .gt. 0 ) then

   do istp = ixostp, nrout

      call xostep( istp, ROUT, MPFL, jxstart, JXEND, PROPAF )
      write(*,*)'range in km (XO region) = ', rout*1.d-3  !Output to screen
      itloss( jxstart:jxend, istp ) = mpfl( 1, jxstart:jxend )
      itpfac( jxstart:jxend, istp ) = mpfl( 2, jxstart:jxend )

      if( lang ) angfac(1:4, jxstart:jxend, istp) = propaf(1:4, jxstart:jxend)

   end do

end if

! If the propagation angles and factors were computed (LANG set to '.true.')
! then output all values in array ANGFAC.

if( lang ) then

   do jk = 1, nrout
      do i = 1, nzout
         angdegD = angfac(1,i,jk) / radc
         if( angfac(1,i,jk) .le. -998.99d0 ) angdegD = -999.d0
         pfd = angfac(2,i,jk)
         if( angfac(2,i,jk) .le. -998.99d0 ) pfd = -999
         angdegR = angfac(3,i,jk) / radc
         if( angfac(3,i,jk) .le. -998.99d0 ) angdegR = -999.d0
         pfr = angfac(4,i,jk)
         if( angfac(4,i,jk) .le. -998.99d0 ) pfr = -999
         write( ioutaf, '(6(f10.2, 2x))') real(jk,8)*drout*1.d-3,
dzout*real(i,8), &
                            angdegD, pfd, angdegR, pfr
      end do
   end do
   close( ioutaf )

end if

!call gettim( ihr2, imin2, isec2, i100th2 )
!time2 = 3600.*ihr2 + 60.*imin2 + isec2 + i100th2/100.

!write(*,*)'Execution time = ', time2-time1, ' secs'

! NOTE: If V pol is specified, then there can be NZOUT + 1 valid loss points
! at each range, where the extra point is stored in MPFL(0).
! IO is a common variable set within APMINIT that equals 0 or 1 depending on the
! polarization used. Therefore, for H pol cases, NZOUT points will be
! written to the file and for V pol cases NZOUT+1 points will be output.

! Now store all loss values in output file FILEOUT.
! Recall that MPFL is the propagation loss/factor in centibels, i.e.,
! MPFL() = NINT( propagation loss/factor in dB * 10. ).

write( ioutf, * )
write( ioutf, * )'********Output Loss and Prop. Factor Values*******'

! Loop for writing propagation loss & factor vs. height for a specified range.

if( nzout .gt. nrout ) then
```

```fortran
   do j = 1, nrout
      write(ioutf,*)
      write(ioutf,'(a,f10.2)')'range in km = ', real(j,8)*drout*1.d-3
      write(ioutf,*)
      write(ioutf,*)'Height(m)   Loss(dB)   PFac(dB) '
      do k = io, nzout
         ploss = itloss(k,j)*.1
         pfac = itpfac(k,j)*.1
         write(ioutf,'(3f10.2)') hmin + real(k,8)*dzout, ploss, pfac
      end do
   end do

else

! Loop for writing propagation loss & factor vs. range for a specified height.

   do k = io, nzout
      write(ioutf,*)
      write(ioutf,'(a,f10.2)')'Height in m = ', real(k,8)*dzout
      write(ioutf,*)
      write(ioutf,*)'Range (km)       Loss (dB)   Prop. factor(dB)  '
      do j = 1, nrout
         ploss = itloss(k,j)*.1
         pfac = itpfac(k,j)*.1
         write(ioutf,'(3f10.2)') real(j,8)*drout*1.d-3, ploss, pfac
      end do
   end do

end if

close(ioutf)

!Deallocate all allocated arrays in main driver program before exiting.

if( allocated( hfang ) ) deallocate( hfang, stat=ierror )
if( ierror .ne. 0 ) then
   write( *, *) '********ERROR IN HFANG DEALLOCATION*******'
   stop
end if

if( allocated( hffac ) ) deallocate( hffac, stat=ierror )
if( ierror .ne. 0 ) then
   write( *, *) '********ERROR IN HFFAC DEALLOCATION*******'
   stop
end if

if( allocated( terx ) ) deallocate( terx, stat=ierror )
if( ierror .ne. 0 ) then
   write( *, *) '********ERROR IN TERX DEALLOCATION*******'
   stop
end if

if( allocated( tery ) ) deallocate( tery, stat=ierror )
if( ierror .ne. 0 ) then
   write( *, *) '********ERROR IN TERY DEALLOCATION*******'
   stop
end if

deallocate( mpfl, itloss, itpfac, mpfl_rtg, cnr_dB, graze_at_rout, &
            propaf )

if( lrtg ) deallocate( zout_rtg )
if( lang ) deallocate( angfac )
```

```
end subroutine runapm

!******************************SUBROUTINE
APMSTATUS***********************************

subroutine apmstatus( lang, r )

implicit integer(kind=4) (i-n)
implicit real(kind=8) (a-h, o-z)

logical(kind=4) lang
real(kind=8) r

!Status for stand-alone APM program.
!****COMMENT THIS LINE IF INCORPORATING INTO OTHER SOFTWARE APPLICATION WITH
GRAPHICS****

if( lang ) then
   write(*,*) 'Computing grazing and propagation angles for range(km) = ',
r*1.d-3
else
   write(*,*) 'Computing grazing angle for range(km) = ', r*1.d-3
end if

end subroutine apmstatus
```

8. INPUT FILE LISTINGS FOR TEST CASES

Each test case, when using the sample driver program APMMAIN.F90, shall consist of an input file (*TestName*.IN) and an output file (*TestName*.OUT). The input file's contents are listed in sections 8.1 through 8.28. The output file's contents, consisting of couplets of height in meters and propagation loss and propagation factor in dB, are listed in Table 33 through Table 80.

8.1 ABSORB.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
20000.    : Frequency in MHz
25.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
5.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0        : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
200.      : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0        : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
.146      : Gaseous absorption attenuation rate in dB/km
0         : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profile in km
0.       350.     : Height & M-unit value of ref. profile 1, level 1
1000.    468.     : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.2 AFEVAP.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
```

```
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.true.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
3000.     : Frequency in MHz
25.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1000.     : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0           : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0           : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
17         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
   0.000    0.00
   0.135  -20.40
   0.223  -21.89
   0.368  -23.37
   0.607  -24.84
   1.000  -26.29
   1.649  -27.71
   2.718  -29.08
   4.482  -30.35
   7.389  -31.49
  12.182  -32.39
  20.086  -32.90
  24.000  -32.95
  33.115  -32.78
  54.598  -31.59
  90.017  -28.66
 148.413  -22.86
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.3 AFSBD.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.true.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
3000.     : Frequency in MHz
25.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
```

```
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
3000.     : Maximum output height in m
100.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0           : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0           : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
4         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.         339.
250.       368.5
300.       319.
1500.     460.6
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.4 AFSTD.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.true.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.     : Frequency in MHz
25.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1000.     : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0           : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0           : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
```

```
1          : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0          : Number of terrain range/height points
```

8.5 AIRBORNE.IN

```
.true.     : LERR6 error flag
.true.     : LERR12 error flag
.false.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.    : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
900.       : Frequency in MHz
2500.      : Antenna height in m
1          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0          : Polarization (0=HOR, 1=VER)
0.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.         : Antenna elevation angle in deg (this value is ignored OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
32.       : Antenna gain in dBi (used for clutter calcs)
1.5        : Horizontal beamwidth in deg (used for clutter calcs)
1.3        : Pulse length in microseconds (used for clutter calcs)
285.       : Transmitter power in kW (used for clutter calcs)
8.4        : System losses in dB (used for clutter calcs)
10.        : Noise figure in dB (used for clutter calcs)
0.         : Minimum output height in m
5000.      : Maximum output height in m
250.       : Maximum output range in km
20         : Number of output height points
1          : Number of output range points
0           : Number of receiver heights relative to ground
0          : Extrapolation flag
0.         : Surface absolute humidity in g/m3
0.         : Surface air temperature in degrees
0.         : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1          : Number of refractivity profiles
5          : Number of levels in refractivity profiles
0.         : Range of first refractivity profile in km
0.           209.2   : Height & M-unit value of ref. profile 1, level 1
1100.          339.  : Height & M-unit value of ref. profile 1, level 2
1500.        386.2   : Height & M-unit value of ref. profile 1, level 3
1625.        361.5   : Height & M-unit value of ref. profile 1, level 4
5625.        833.5    : Height & M-unit value of ref. profile 1, level 5
0.         : Wind direction in deg (only used for clutter calcs)
1          : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1          : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0          : Number of terrain range/height points
```

8.6 BLOCK.IN

```
.true.     : LERR6 error flag
.true.     : LERR12 error flag
.false.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.    : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.      : Frequency in MHz
101.       : Antenna height in m
1          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1          : Polarization (0=HOR, 1=VER)
0.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
```

```
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
400.      : Maximum output height in m
60.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
7.5       : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0         : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profile in km
0       350     : Height & M-unit value of ref. profile 1, level 1
1000    468     : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 7,  7.5, 0.01     : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
6         : Number of terrain range/height points
0.     1       : Range(km) & height of terrain point 1
10.0   1       : Range(km) & height of terrain point 2
10.0    200
40.0    200
40.0    1
60.0    1
```

8.7 CLEVAPW.IN

```
.false.   : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.       : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored otherwise)
1.       : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.true.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
10000.   : Frequency in MHz
25.       : Antenna height in m
3         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
2.        : Beamwidth in deg (this value is ignored for OMNI and USRDEF antenna)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI and USRDEF antenna)
0        : Number of angle/factor pairs (used for antenna types 6 and 7)
32.      : Antenna gain in dBi (used for clutter calcs)
1.5       : Horizontal beamwidth in deg (used for clutter calcs)
1.3       : Pulse length in microseconds (used for clutter calcs)
285.      : Transmitter power in kW (used for clutter calcs)
8.4       : System losses in dB (used for clutter calcs)
10.       : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1000.     : Maximum output height in m
100.      : Maximum output range in km
2         : Number of output height points
100       : Number of output range points
0        : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
1        : Number of wind speeds/ranges specified
10., 0.   : Wind speed (m/s), range (km)
1         : Number of refractivity profiles
```

```
50        : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.000000       339.000000
0.833333       318.405284
1.666667       316.841934
2.500000       315.968883
3.333333       315.378476
4.166667       314.942950
5.000000       314.605389
5.833333       314.335435
6.666667       314.114965
7.500000       313.932289
8.333333       313.779427
9.166667       313.650685
10.000000      313.541859
10.833333      313.449758
11.666667      313.371900
12.500000      313.306318
13.333333      313.251426
14.166667      313.205927
15.000000      313.168748
15.833333      313.138987
16.666667      313.115883
17.500000      313.098787
18.333333      313.087139
19.166667      313.080455
20.000000      313.078311
20.833333      313.080339
21.666667      313.086209
22.500000      313.095632
23.333333      313.108350
24.166667      313.124130
25.000000      313.142767
25.833333      313.164071
26.666667      313.187874
27.500000      313.214022
28.333333      313.242374
29.166667      313.272804
30.000000      313.305194
30.833333      313.339436
31.666667      313.375432
32.500000      313.413091
33.333333      313.452328
34.166667      313.493066
35.000000      313.535231
35.833333      313.578758
36.666667      313.623583
37.500000      313.669648
38.333333      313.716898
39.166667      313.765283
40.000000      313.814755
1200.000000    444.851829
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0.,0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.8 CLSBDL.IN

```
.false.   : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.        : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored otherwise)
1.        : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.true.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
10000.    : Frequency in MHz
25.       : Antenna height in m
3         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
```

```
1         : Polarization (0=HOR, 1=VER)
2.        : Beamwidth in deg (this value is ignored for OMNI and USRDEF antenna)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI and USRDEF antenna)
0         : Number of angle/factor pairs (used for antenna types 6 and 7)
32.       : Antenna gain in dBi (used for clutter calcs)
1.5       : Horizontal beamwidth in deg (used for clutter calcs)
1.3       : Pulse length in microseconds (used for clutter calcs)
285.      : Transmitter power in kW (used for clutter calcs)
8.4       : System losses in dB (used for clutter calcs)
10.       : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1000.     : Maximum output height in m
100.      : Maximum output range in km
2         : Number of output height points
100       : Number of output range points
0         : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
1         : Number of wind speeds/ranges specified
10., 0.   : Wind speed (m/s), range (km)
1         : Number of refractivity profiles
50        : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.000000       339.000000
0.833333       318.405284
1.666667       316.841934
2.500000       315.968883
3.333333       315.378476
4.166667       314.942950
5.000000       314.605389
5.833333       314.335435
6.666667       314.114965
7.500000       313.932289
8.333333       313.779427
9.166667       313.650685
10.000000      313.541859
10.833333      313.449758
11.666667      313.371900
12.500000      313.306318
13.333333      313.251426
14.166667      313.205927
15.000000      313.168748
15.833333      313.138987
16.666667      313.115883
17.500000      313.098787
18.333333      313.087139
19.166667      313.080455
20.000000      313.078311
20.833333      313.080339
21.666667      313.086209
22.500000      313.095632
23.333333      313.108350
24.166667      313.124130
25.000000      313.142767
25.833333      313.164071
26.666667      313.187874
27.500000      313.214022
28.333333      313.242374
29.166667      313.272804
30.000000      313.305194
30.833333      313.339436
31.666667      313.375432
32.500000      313.413091
33.333333      313.452328
34.166667      313.493066
35.000000      313.535231
35.833333      313.578758
36.666667      313.623583
37.500000      313.669648
38.333333      313.716898
39.166667      313.765283
40.000000      313.814755
1200.000000    444.851829
```

```
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0.,0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.9 CLSBDW.IN

```
.false.   : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.        : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored otherwise)
1.        : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.true.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
3000.     : Frequency in MHz
15.       : Antenna height in m
5         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
1.5       : Beamwidth in deg (this value is ignored for OMNI and USRDEF antenna)
0.5       : Antenna elevation angle in deg (this value is ignored for OMNI and USRDEF antenna)
0         : Number of angle/factor pairs (used for antenna types 6 and 7)
39.       : Antenna gain in dBi
2.0       : Horizontal beamwidth in deg
9.        : Pulse length in microseconds
2000.     : Transmitter power in kW
3.        : System losses in dB
5.5       : Noise figure in dB
0.        : Minimum output height in m
1000.     : Maximum output height in m
100.      : Maximum output range in km
2         : Number of output height points
100       : Number of output range points
0         : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
1         : Number of wind speeds/ranges specified
10., 0.   :  Wind speed (m/s), range (km)
1         : Number of refractivity profiles
4         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.         339.
250.       368.5
300.       319.
1500.     460.6
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0.,0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
0         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
0         : Number of terrain range/height points
```

8.10 CLSBDWL.IN

```
.false.   : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.        : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored otherwise)
1.        : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.true.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
5600.     : Frequency in MHz
15.       : Antenna height in m
3         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
16.       : Beamwidth in deg (this value is ignored for OMNI and USRDEF antenna)
```

```
0.        : Antenna elevation angle in deg (this value is ignored for OMNI and USRDEF antenna)
0        : Number of angle/factor pairs (used for antenna types 6 and 7)
30.      : Antenna gain in dBi
1.5       : Horizontal beamwidth in deg
1.3       : Pulse length in microseconds
230.      : Transmitter power in kW
3.        : System losses in dB
5.        : Noise figure in dB
0.        : Minimum output height in m
3000.     : Maximum output height in m
200.      : Maximum output range in km
2         : Number of output height points
100       : Number of output range points
0        : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
1        : Number of wind speeds/ranges specified
10., 0.   :  Wind speed (m/s), range (km)
1         : Number of refractivity profiles
4         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.         339.
250.       368.5
300.       319.
1500.     460.6
45.        : Wind direction in deg (only used for clutter calcs)
2         : Number of ground composition types
0.,0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
100.,4, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
2         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-5., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
-10., 100.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
265         : Number of terrain range/height points
0      0
100    0
100.5682       2
101.1364       2
101.7045       2
102.2727       3
102.8409       4
103.4091       5
103.9773       4
104.5455       7
105.1136       6
105.6818       9
106.25  12
106.8182       9
107.3864       9
107.9545       8
108.5227       10
109.0909       19
109.6591       21
110.2273       27
110.7955       32
111.3636       32
111.9318       47
112.5   43
113.0682       58
113.6364       82
114.2045       75
114.7727       96
115.3409       63
115.9091       100
116.4773       123
117.0455       98
117.6136       95
118.1818       100
118.75  106
119.3182       100
119.8864       108
120.4545       89
121.0227       90
121.5909       95
```

122.1591	89
122.7273	107
123.2955	97
123.8636	108
124.4318	87
125	76
125.5682	73
126.1364	88
126.7045	86
127.2727	101
127.8409	101
128.4091	92
128.9773	65
129.5455	62
130.1136	47
130.6818	59
131.25	44
131.8182	33
132.3864	21
132.9545	20
133.5227	21
134.0909	11
134.6591	7
135.2273	7
135.7955	4
136.3636	12
136.9318	9
137.5	6
138.0682	5
138.6364	7
139.2045	5
139.7727	8
140.3409	14
140.9091	7
141.4773	12
142.0455	10
142.6136	8
143.1818	14
143.75	15
144.3182	18
144.8864	29
145.4545	78
146.0227	76
146.5909	89
147.1591	139
147.7273	168
148.2955	173
148.8636	184
149.4318	193
150	232
150.5682	227
151.1364	264
151.7045	222
152.2727	267
152.8409	247
153.4091	287
153.9773	363
154.5455	427
155.1136	399
155.6818	344
156.25	258
156.8182	188
157.3864	182
157.9545	94
158.5227	85
159.0909	63
159.6591	43
160.2273	18
160.7955	16
161.3636	16
161.9318	13
162.5	21
163.0682	20
163.6364	22
164.2045	26

164.7727	27
165.3409	31
165.9091	45
166.4773	58
167.0455	64
167.6136	87
168.1818	92
168.75	112
169.3182	124
169.8864	144
170.4545	178
171.0227	154
171.5909	172
172.1591	192
172.7273	192
173.2955	196
173.8636	216
174.4318	222
175	234
175.5682	236
176.1364	262
176.7045	287
177.2727	372
177.8409	546
178.4091	699
178.9773	821
179.5455	682
180.1136	544
180.6818	477
181.25	509
181.8182	510
182.3864	546
182.9545	582
183.5227	844
184.0909	873
184.6591	776
185.2273	819
185.7955	830
186.3636	814
186.9318	860
187.5	870
188.0682	993
188.6364	901
189.2045	886
189.7727	946
190.3409	911
190.9091	1025
191.4773	1123
192.0455	1262
192.6136	1424
193.1818	1460
193.75	1442
194.3182	1348
194.8864	1152
195.4545	940
196.0227	1256
196.5909	1111
197.1591	943
197.7273	1037
198.2955	931
198.8636	759
199.4318	673
200	702
200.5682	607
201.1364	649
201.7045	576
202.2727	551
202.8409	548
203.4091	548
203.9773	551
204.5455	546
205.1136	545
205.6818	547
206.25	556
206.8182	569

207.3864	576
207.9545	610
208.5227	636
209.0909	634
209.6591	704
210.2273	736
210.7955	719
211.3636	702
211.9318	714
212.5	691
213.0682	676
213.6364	671
214.2045	671
214.7727	708
215.3409	668
215.9091	674
216.4773	688
217.0455	638
217.6136	661
218.1818	652
218.75	673
219.3182	673
219.8864	665
220.4545	703
221.0227	671
221.5909	685
222.1591	730
222.7273	722
223.2955	737
223.8636	709
224.4318	752
225	767
225.5682	774
226.1364	728
226.7045	749
227.2727	761
227.8409	759
228.4091	815
228.9773	836
229.5455	896
230.1136	924
230.6818	956
231.25	1136
231.8182	1187
232.3864	1353
232.9545	1313
233.5227	1153
234.0909	1111
234.6591	1095
235.2273	1094
235.7955	1249
236.3636	1334
236.9318	1286
237.5	1235
238.0682	1181
238.6364	1165
239.2045	1196
239.7727	1207
240.3409	1257
240.9091	1177
241.4773	1237
242.0455	1186
242.6136	1085
243.1818	964
243.75	897
244.3182	861
244.8864	806
245.4545	796
246.0227	780
246.5909	773
247.1591	767
247.7273	764
248.2955	761
248.8636	753
249.4318	750

8.11 COSEC2.IN

```
.true.     : LERR6 error flag
.true.     : LERR12 error flag
.false.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.     : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored otherwise)
1.      : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.    : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.      : Frequency in MHz
25.        : Antenna height in m
4          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0          : Polarization (0=HOR, 1=VER)
1.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.         : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0      : Number of cut-back angles and factors (used for specific height-finder antenna)
0.                    : Antenna gain in dBi  (used for clutter calcs)
0.         : Horizontal beamwidth in deg (used for clutter calcs)
0.         : Pulse length in microseconds (used for clutter calcs)
0.         : Transmitter power in kW (used for clutter calcs)
0.         : System losses in dB (used for clutter calcs)
0.         : Noise figure in dB (used for clutter calcs)
0.         : Minimum output height in m
2000.      : Maximum output height in m
50.        : Maximum output range in km
20         : Number of output height points
1          : Number of output range points
0                     : Number of receiver heights relative to ground
0          : Extrapolation flag
0.         : Surface absolute humidity in g/m3
0.         : Surface air temperature in degrees
0.         : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1          : Number of refractivity profiles
2          : Number of levels in refractivity profiles
0.         : Range of first refractivity profiles in km
0.           350.    : Height & M-unit value of ref. profile 1, level 1
1000.        468.    : Height & M-unit value of ref. profile 1, level 2
0.         : Wind direction in deg (only used for clutter calcs)
1          : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1          : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0          : Number of terrain range/height points
```

8.12 EDUCT.IN

```
.true.     : LERR6 error flag
.true.     : LERR12 error flag
.false.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.    : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
10000.     : Frequency in MHz
15.        : Antenna height in m
2          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0          : Polarization (0=HOR, 1=VER)
5.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.         : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.         : Horizontal beamwidth in deg (used for clutter calcs)
0.         : Pulse length in microseconds (used for clutter calcs)
0.         : Transmitter power in kW (used for clutter calcs)
0.         : System losses in dB (used for clutter calcs)
```

```
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
200.      : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0        : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0         : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
21        : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.       339.     : Height & M-unit value of ref. profile 1, level 1
.040     335.10   : Height & M-unit value of ref. profile 1, level 2
.1       333.66   : Height & M-unit value of ref. profile 1, level 3
.2       332.6    : Height & M-unit value of ref. profile 1, level 4
.398     331.54   : Height & M-unit value of ref. profile 1, level 5
.794     330.51   : Height & M-unit value of ref. profile 1, level 6
1.585    329.53   : Height & M-unit value of ref. profile 1, level 7
3.162    328.65   : Height & M-unit value of ref. profile 1, level 8
6.310    327.96   : Height & M-unit value of ref. profile 1, level 9
12.589   327.68   : Height & M-unit value of ref. profile 1, level 10
14.      327.67   : Height & M-unit value of ref. profile 1, level 11
25.119   328.13   : Height & M-unit value of ref. profile 1, level 12
39.811   329.25   : Height & M-unit value of ref. profile 1, level 13
50.119   330.18   : Height & M-unit value of ref. profile 1, level 14
63.096   331.44   : Height & M-unit value of ref. profile 1, level 15
79.433   333.12   : Height & M-unit value of ref. profile 1, level 16
100.     335.33   : Height & M-unit value of ref. profile 1, level 17
125.893  338.2    : Height & M-unit value of ref. profile 1, level 18
158.489  341.92   : Height & M-unit value of ref. profile 1, level 19
199.526  346.69   : Height & M-unit value of ref. profile 1, level 20
209.526  347.87   : Height & M-unit value of ref. profile 1, level 21
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # OF GAMMAC/GAMRNG PAIRS IS 0)0         :
Number of terrain range/height points
```

8.13 EDUCTRF.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
10000.    : Frequency in MHz
15.       : Antenna height in m
2         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
5.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
200.      : Maximum output height in m
100.      : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
```

```
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
1          : Number of wind speeds/ranges specified
10., 0.   : Wind speed (m/s), Range(km)
1         : Number of refractivity profiles
21        : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.       339.     : Height & M-unit value of ref. profile 1, level 1
.040     335.10   : Height & M-unit value of ref. profile 1, level 2
.1       333.66   : Height & M-unit value of ref. profile 1, level 3
.2       332.6    : Height & M-unit value of ref. profile 1, level 4
.398     331.54   : Height & M-unit value of ref. profile 1, level 5
.794     330.51   : Height & M-unit value of ref. profile 1, level 6
1.585    329.53   : Height & M-unit value of ref. profile 1, level 7
3.162    328.65   : Height & M-unit value of ref. profile 1, level 8
6.310    327.96   : Height & M-unit value of ref. profile 1, level 9
12.589   327.68   : Height & M-unit value of ref. profile 1, level 10
14.      327.67   : Height & M-unit value of ref. profile 1, level 11
25.119   328.13   : Height & M-unit value of ref. profile 1, level 12
39.811   329.25   : Height & M-unit value of ref. profile 1, level 13
50.119   330.18   : Height & M-unit value of ref. profile 1, level 14
63.096   331.44   : Height & M-unit value of ref. profile 1, level 15
79.433   333.12   : Height & M-unit value of ref. profile 1, level 16
100.     335.33   : Height & M-unit value of ref. profile 1, level 17
125.893  338.2    : Height & M-unit value of ref. profile 1, level 18
158.489  341.92   : Height & M-unit value of ref. profile 1, level 19
199.526  346.69   : Height & M-unit value of ref. profile 1, level 20
209.526  347.87   : Height & M-unit value of ref. profile 1, level 21
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.14 FLTA50.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.     : Frequency in MHz
50.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
5.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
100.      : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0         : Number of wind speeds/ranges specified
```

```
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.       350.     : Height & M-unit value of ref. profile 1, level 1
1000.     468.     : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 7, 7., 0.01   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
2         : Number of terrain range/height points
0.     10
50.0   10
```

8.15 GASABS.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
20000.    : Frequency in MHz
25.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
5.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
200.      : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
10.       : Surface absolute humidity in g/m3
25.       : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.16 GAUSS.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
```

```
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.     : Frequency in MHz
25.       : Antenna height in m
2         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
1.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
2000.     : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.17 HEIGHT_RTG

```
.false.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
162.4     : Frequency in MHz
54.864      : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of angle/factor pairs (used for antenna types 6 and 7)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
500.      : Maximum output height in m
18.41     : Maximum output range in km
1         : Number of output height points
20        : Number of output range points
3          : Number of receiver heights relative to ground
1.2     : Receiver heights in meters relative to ground (remove line if #of Rx heights is 0)
2.5     : Receiver heights in meters relative to ground (remove line if #of Rx heights is 0)
5.1     : Receiver heights in meters relative to ground (remove line if #of Rx heights is 0)
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
```

```
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.       350.       : Height & M-unit value of ref. profile 1, level 1
1000.    468.       : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0.,3, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
304         : Number of terrain range/height points
  0.0000000e+000  2.9950500e+002
  6.0761706e-002  2.9310199e+002
  1.2152341e-001  2.8529070e+002
  1.8228512e-001  2.7547598e+002
  2.4304682e-001  2.7400000e+002
  3.0380853e-001  2.8218547e+002
  3.6457023e-001  2.9534749e+002
  4.2533194e-001  3.0293684e+002
  4.8609365e-001  3.0329591e+002
  5.4685543e-001  3.0301469e+002
  6.0761713e-001  3.0400000e+002
  6.6837891e-001  3.0374435e+002
  7.2914069e-001  3.0016827e+002
  7.8990240e-001  2.9682011e+002
  8.5066410e-001  2.9299658e+002
  9.1142588e-001  2.8775906e+002
  9.7218759e-001  2.8185390e+002
  1.0329493e+000  2.7664625e+002
  1.0937111e+000  2.7279881e+002
  1.1544729e+000  2.6911534e+002
  1.2152346e+000  2.6361136e+002
  1.2759963e+000  2.5725418e+002
  1.3367580e+000  2.4591124e+002
  1.3975197e+000  2.4389800e+002
  1.4582814e+000  2.4315492e+002
  1.5190431e+000  2.4032027e+002
  1.5798048e+000  2.3723561e+002
  1.6405665e+000  2.3557093e+002
  1.7013282e+000  2.3314804e+002
  1.7620899e+000  2.2832272e+002
  1.8228516e+000  2.2403300e+002
  1.8836133e+000  2.1926640e+002
  1.9443750e+000  2.1450175e+002
  2.0051368e+000  2.1318040e+002
  2.0658985e+000  2.1300000e+002
  2.1266602e+000  2.1257439e+002
  2.1874219e+000  2.1103692e+002
  2.2481836e+000  2.0862110e+002
  2.3089453e+000  2.0592163e+002
  2.3697070e+000  2.0322217e+002
  2.4304687e+000  2.0052271e+002
  2.4912305e+000  1.9778542e+002
  2.5519922e+000  1.9450880e+002
  2.6127540e+000  1.9178333e+002
  2.6735157e+000  1.8908433e+002
  2.7342773e+000  1.8638532e+002
  2.7950390e+000  1.8460125e+002
  2.8558007e+000  1.8354216e+002
  2.9165624e+000  1.8300000e+002
  2.9773241e+000  1.8274251e+002
  3.0380859e+000  1.8200000e+002
  3.0988476e+000  1.8200000e+002
  3.1596093e+000  1.8200000e+002
  3.2203710e+000  1.7958674e+002
  3.2811327e+000  1.7464175e+002
  3.3418944e+000  1.6924086e+002
  3.4026561e+000  1.6459898e+002
  3.4634178e+000  1.6071616e+002
  3.5241795e+000  1.5688949e+002
  3.5849412e+000  1.5341644e+002
  3.6457029e+000  1.5127932e+002
  3.7064646e+000  1.4716528e+002
```

3.7672263e+000	1.4389636e+002
3.8279881e+000	1.3923192e+002
3.8887498e+000	1.3421815e+002
3.9495115e+000	1.2808321e+002
4.0102732e+000	1.2426357e+002
4.0710348e+000	1.2304306e+002
4.1317965e+000	1.2284360e+002
4.1925582e+000	1.2309907e+002
4.2533201e+000	1.2394364e+002
4.3140818e+000	1.2442499e+002
4.3748436e+000	1.2352635e+002
4.4356053e+000	1.2348088e+002
4.4963670e+000	1.2320301e+002
4.5571287e+000	1.2245950e+002
4.6178904e+000	1.2190808e+002
4.6786521e+000	1.2169107e+002
4.7394138e+000	1.2153794e+002
4.8001755e+000	1.2127808e+002
4.8609372e+000	1.2213782e+002
4.9216989e+000	1.2863134e+002
4.9824606e+000	1.3110240e+002
5.0432223e+000	1.3016863e+002
5.1039840e+000	1.2942360e+002
5.1647457e+000	1.2834528e+002
5.2255074e+000	1.2642025e+002
5.2862691e+000	1.2417204e+002
5.3470308e+000	1.2260712e+002
5.4077925e+000	1.2218517e+002
5.4685543e+000	1.2197993e+002
5.5293160e+000	1.1954888e+002
5.5900777e+000	1.1594994e+002
5.6508394e+000	1.1235100e+002
5.7116012e+000	1.0950149e+002
5.7723629e+000	1.0639660e+002
5.8331246e+000	1.0313536e+002
5.8938865e+000	1.0015476e+002
5.9546483e+000	9.7891421e+001
6.0154100e+000	9.6564563e+001
6.0761717e+000	9.6000000e+001
6.1369335e+000	9.6030080e+001
6.1976953e+000	9.6591542e+001
6.2584570e+000	9.7471706e+001
6.3192187e+000	9.8371421e+001
6.3799804e+000	9.9271143e+001
6.4407422e+000	1.0017087e+002
6.5015040e+000	1.0107060e+002
6.5622658e+000	1.0197034e+002
6.6230275e+000	1.0311686e+002
6.6837892e+000	1.0476984e+002
6.7445509e+000	1.0571601e+002
6.8053127e+000	1.0751559e+002
6.8660744e+000	1.0899628e+002
6.9268362e+000	1.1027310e+002
6.9875980e+000	1.1191438e+002
7.0483599e+000	1.1371398e+002
7.1091217e+000	1.1551360e+002
7.1698835e+000	1.1731322e+002
7.2306452e+000	1.1911284e+002
7.2914070e+000	1.2085786e+002
7.3521688e+000	1.2243519e+002
7.4129305e+000	1.2625557e+002
7.4736924e+000	1.2986853e+002
7.5344542e+000	1.3393133e+002
7.5952161e+000	1.3809119e+002
7.6559780e+000	1.4313355e+002
7.7167398e+000	1.4659434e+002
7.7775017e+000	1.4817706e+002
7.8382635e+000	1.4988962e+002
7.8990254e+000	1.5039665e+002
7.9597872e+000	1.5057576e+002
8.0205491e+000	1.4989814e+002
8.0813109e+000	1.4648570e+002
8.1420727e+000	1.4835292e+002
8.2028345e+000	1.5058030e+002
8.2635962e+000	1.5133977e+002

8.3243579e+000	1.5134179e+002
8.3851197e+000	1.5134395e+002
8.4458815e+000	1.5134624e+002
8.5066434e+000	1.5134867e+002
8.5674052e+000	1.5135123e+002
8.6281670e+000	1.5135393e+002
8.6889288e+000	1.4873290e+002
8.7496905e+000	1.4685104e+002
8.8104523e+000	1.4540519e+002
8.8712141e+000	1.4425930e+002
8.9319758e+000	1.4121540e+002
8.9927375e+000	1.3740409e+002
9.0534993e+000	1.3514239e+002
9.1142610e+000	1.3187107e+002
9.1750227e+000	1.3348579e+002
9.2357844e+000	1.3596048e+002
9.2965462e+000	1.3895951e+002
9.3573079e+000	1.4199633e+002
9.4180696e+000	1.4527156e+002
9.4788314e+000	1.4951941e+002
9.5395931e+000	1.5200000e+002
9.6003548e+000	1.5200000e+002
9.6611165e+000	1.5214912e+002
9.7218782e+000	1.5276486e+002
9.7826400e+000	1.5369799e+002
9.8434017e+000	1.5539260e+002
9.9041634e+000	1.5802300e+002
9.9649251e+000	1.6164928e+002
1.0025687e+001	1.6508088e+002
1.0086448e+001	1.6942093e+002
1.0147210e+001	1.7460048e+002
1.0207972e+001	1.7792114e+002
1.0268734e+001	1.7792418e+002
1.0329495e+001	1.7782666e+002
1.0390257e+001	1.7720373e+002
1.0451019e+001	1.7754017e+002
1.0511780e+001	1.7787615e+002
1.0572542e+001	1.7682012e+002
1.0633304e+001	1.7688705e+002
1.0694065e+001	1.7788968e+002
1.0754827e+001	1.7971680e+002
1.0815589e+001	1.8311357e+002
1.0876351e+001	1.8702959e+002
1.0937112e+001	1.8758687e+002
1.0997874e+001	1.8618577e+002
1.1058636e+001	1.8496084e+002
1.1119397e+001	1.8154109e+002
1.1180159e+001	1.7687416e+002
1.1240921e+001	1.7082137e+002
1.1301683e+001	1.6622341e+002
1.1362444e+001	1.6240798e+002
1.1423206e+001	1.5920693e+002
1.1483968e+001	1.5747477e+002
1.1544729e+001	1.5420958e+002
1.1605491e+001	1.5214325e+002
1.1666253e+001	1.5615842e+002
1.1727015e+001	1.5805664e+002
1.1787776e+001	1.5844509e+002
1.1848538e+001	1.5887424e+002
1.1909300e+001	1.5964437e+002
1.1970061e+001	1.5940992e+002
1.2030823e+001	1.5826843e+002
1.2091585e+001	1.5718705e+002
1.2152347e+001	1.5500000e+002
1.2213108e+001	1.5500000e+002
1.2273870e+001	1.5500000e+002
1.2334632e+001	1.5500000e+002
1.2395393e+001	1.5500000e+002
1.2456155e+001	1.5500000e+002
1.2516917e+001	1.5500000e+002
1.2577678e+001	1.5500000e+002
1.2638440e+001	1.5500000e+002
1.2699202e+001	1.5500000e+002
1.2759964e+001	1.5500000e+002
1.2820725e+001	1.5500000e+002

1.2881487e+001	1.5500000e+002
1.2942249e+001	1.5500000e+002
1.3003010e+001	1.5500000e+002
1.3063772e+001	1.5500000e+002
1.3124534e+001	1.5500000e+002
1.3185295e+001	1.5500000e+002
1.3246057e+001	1.5500000e+002
1.3306819e+001	1.5500000e+002
1.3367581e+001	1.5500000e+002
1.3428342e+001	1.5500000e+002
1.3489104e+001	1.5500000e+002
1.3549866e+001	1.5500000e+002
1.3610627e+001	1.5500000e+002
1.3671389e+001	1.5500000e+002
1.3732151e+001	1.5500000e+002
1.3792913e+001	1.5500000e+002
1.3853674e+001	1.5500000e+002
1.3914436e+001	1.5500000e+002
1.3975198e+001	1.5500000e+002
1.4035960e+001	1.5500000e+002
1.4096721e+001	1.5500000e+002
1.4157483e+001	1.5500000e+002
1.4218245e+001	1.5500000e+002
1.4279007e+001	1.5500000e+002
1.4339768e+001	1.5500000e+002
1.4400530e+001	1.5500000e+002
1.4461292e+001	1.5510919e+002
1.4522054e+001	1.5533661e+002
1.4582815e+001	1.5533592e+002
1.4643577e+001	1.5532745e+002
1.4704339e+001	1.5502576e+002
1.4765100e+001	1.5500000e+002
1.4825862e+001	1.5500000e+002
1.4886624e+001	1.5500000e+002
1.4947385e+001	1.5500000e+002
1.5008147e+001	1.5500000e+002
1.5068909e+001	1.5500000e+002
1.5129671e+001	1.5500000e+002
1.5190432e+001	1.5552616e+002
1.5251194e+001	1.5942040e+002
1.5311956e+001	1.6331327e+002
1.5372718e+001	1.6666884e+002
1.5433479e+001	1.6948810e+002
1.5494241e+001	1.7238837e+002
1.5555003e+001	1.7468900e+002
1.5615765e+001	1.7677150e+002
1.5676526e+001	1.7864255e+002
1.5737288e+001	1.7969076e+002
1.5798050e+001	1.8111975e+002
1.5858812e+001	1.8200000e+002
1.5919573e+001	1.8200000e+002
1.5980335e+001	1.8200000e+002
1.6041097e+001	1.8200000e+002
1.6101859e+001	1.8200000e+002
1.6162620e+001	1.8200000e+002
1.6223382e+001	1.8200000e+002
1.6284144e+001	1.8200000e+002
1.6344906e+001	1.8200000e+002
1.6405668e+001	1.8200000e+002
1.6466430e+001	1.8200000e+002
1.6527191e+001	1.8200000e+002
1.6587953e+001	1.8200000e+002
1.6648715e+001	1.8200000e+002
1.6709476e+001	1.8200000e+002
1.6770238e+001	1.8200000e+002
1.6831000e+001	1.8200000e+002
1.6891762e+001	1.8200000e+002
1.6952524e+001	1.8200000e+002
1.7013286e+001	1.8200000e+002
1.7074047e+001	1.8200000e+002
1.7134809e+001	1.8200000e+002
1.7195571e+001	1.8200000e+002
1.7256332e+001	1.8200000e+002
1.7317094e+001	1.8655453e+002
1.7377856e+001	1.9146493e+002

```
  1.7438618e+001  1.9382147e+002
  1.7499379e+001  1.9409382e+002
  1.7560141e+001  1.9341049e+002
  1.7620903e+001  1.9333171e+002
  1.7681665e+001  1.9270308e+002
  1.7742426e+001  1.9244155e+002
  1.7803188e+001  1.9184128e+002
  1.7863950e+001  1.9150346e+002
  1.7924712e+001  1.9142251e+002
  1.7985473e+001  1.9142456e+002
  1.8046235e+001  1.9101353e+002
  1.8106997e+001  1.9011578e+002
  1.8167759e+001  1.8943076e+002
  1.8228520e+001  1.8954540e+002
  1.8289282e+001  1.9045081e+002
  1.8350044e+001  1.9160600e+002
  1.8410806e+001  1.9311592e+002
```

8.18 HF10TER

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
10.        : Frequency in MHz
20.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
2000.      : Maximum output height in m
249.      : Maximum output range in km
2.        : Number of output height points
30        : Number of output range points
0        : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0        : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
2         : Number of ground composition types
0., 7, 80., 4.   : Range(km), ground type (integer), permittivity, conductivity
80., 7, 5.0, .0001 : Range(km), ground type (integer), permittivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
265         : Number of terrain range/height points
           0.0          0.0
      100.0000          0.0
      100.5682          2.0
      101.1364          2.0
      101.7045          2.0
      102.2727          3.0
      102.8409          4.0
```

103.4091	5.0
103.9773	4.0
104.5455	7.0
105.1136	6.0
105.6818	9.0
106.2500	12.0
106.8182	9.0
107.3864	9.0
107.9545	8.0
108.5227	10.0
109.0909	19.0
109.6591	21.0
110.2273	27.0
110.7955	32.0
111.3636	32.0
111.9318	47.0
112.5000	43.0
113.0682	58.0
113.6364	82.0
114.2045	75.0
114.7727	96.0
115.3409	63.0
115.9091	100.0
116.4773	123.0
117.0455	98.0
117.6136	95.0
118.1818	100.0
118.7500	106.0
119.3182	100.0
119.8864	108.0
120.4545	89.0
121.0227	90.0
121.5909	95.0
122.1591	89.0
122.7273	107.0
123.2955	97.0
123.8636	108.0
124.4318	87.0
125.0000	76.0
125.5682	73.0
126.1364	88.0
126.7045	86.0
127.2727	101.0
127.8409	101.0
128.4091	92.0
128.9773	65.0
129.5455	62.0
130.1136	47.0
130.6818	59.0
131.2500	44.0
131.8182	33.0
132.3864	21.0
132.9545	20.0
133.5227	21.0
134.0909	11.0
134.6591	7.0
135.2273	7.0
135.7955	4.0
136.3636	12.0
136.9318	9.0
137.5000	6.0
138.0682	5.0
138.6364	7.0
139.2045	5.0
139.7727	8.0
140.3409	14.0
140.9091	7.0
141.4773	12.0
142.0455	10.0
142.6136	8.0
143.1818	14.0
143.7500	15.0
144.3182	18.0
144.8864	29.0
145.4545	78.0

146.0227	76.0
146.5909	89.0
147.1591	139.0
147.7273	168.0
148.2955	173.0
148.8636	184.0
149.4318	193.0
150.0000	232.0
150.5682	227.0
151.1364	264.0
151.7045	222.0
152.2727	267.0
152.8409	247.0
153.4091	287.0
153.9773	363.0
154.5455	427.0
155.1136	399.0
155.6818	344.0
156.2500	258.0
156.8182	188.0
157.3864	182.0
157.9545	94.0
158.5227	85.0
159.0909	63.0
159.6591	43.0
160.2273	18.0
160.7955	16.0
161.3636	16.0
161.9318	13.0
162.5000	21.0
163.0682	20.0
163.6364	22.0
164.2045	26.0
164.7727	27.0
165.3409	31.0
165.9091	45.0
166.4773	58.0
167.0455	64.0
167.6136	87.0
168.1818	92.0
168.7500	112.0
169.3182	124.0
169.8864	144.0
170.4545	178.0
171.0227	154.0
171.5909	172.0
172.1591	192.0
172.7273	192.0
173.2955	196.0
173.8636	216.0
174.4318	222.0
175.0000	234.0
175.5682	236.0
176.1364	262.0
176.7045	287.0
177.2727	372.0
177.8409	546.0
178.4091	699.0
178.9773	821.0
179.5455	682.0
180.1136	544.0
180.6818	477.0
181.2500	509.0
181.8182	510.0
182.3864	546.0
182.9545	582.0
183.5227	844.0
184.0909	873.0
184.6591	776.0
185.2273	819.0
185.7955	830.0
186.3636	814.0
186.9318	860.0
187.5000	870.0
188.0682	993.0

188.6364	901.0
189.2045	886.0
189.7727	946.0
190.3409	911.0
190.9091	1025.0
191.4773	1123.0
192.0455	1262.0
192.6136	1424.0
193.1818	1460.0
193.7500	1442.0
194.3182	1348.0
194.8864	1152.0
195.4545	940.0
196.0227	1256.0
196.5909	1111.0
197.1591	943.0
197.7273	1037.0
198.2955	931.0
198.8636	759.0
199.4318	673.0
200.0000	702.0
200.5682	607.0
201.1364	649.0
201.7045	576.0
202.2727	551.0
202.8409	548.0
203.4091	548.0
203.9773	551.0
204.5455	546.0
205.1136	545.0
205.6818	547.0
206.2500	556.0
206.8182	569.0
207.3864	576.0
207.9545	610.0
208.5227	636.0
209.0909	634.0
209.6591	704.0
210.2273	736.0
210.7955	719.0
211.3636	702.0
211.9318	714.0
212.5000	691.0
213.0682	676.0
213.6364	671.0
214.2045	671.0
214.7727	708.0
215.3409	668.0
215.9091	674.0
216.4773	688.0
217.0455	638.0
217.6136	661.0
218.1818	652.0
218.7500	673.0
219.3182	673.0
219.8864	665.0
220.4545	703.0
221.0227	671.0
221.5909	685.0
222.1591	730.0
222.7273	722.0
223.2955	737.0
223.8636	709.0
224.4318	752.0
225.0000	767.0
225.5682	774.0
226.1364	728.0
226.7045	749.0
227.2727	761.0
227.8409	759.0
228.4091	815.0
228.9773	836.0
229.5455	896.0
230.1136	924.0
230.6818	956.0

```
231.2500        1136.0
231.8182        1187.0
232.3864        1353.0
232.9545        1313.0
233.5227        1153.0
234.0909        1111.0
234.6591        1095.0
235.2273        1094.0
235.7955        1249.0
236.3636        1334.0
236.9318        1286.0
237.5000        1235.0
238.0682        1181.0
238.6364        1165.0
239.2045        1196.0
239.7727        1207.0
240.3409        1257.0
240.9091        1177.0
241.4773        1237.0
242.0455        1186.0
242.6136        1085.0
243.1818         964.0
243.7500         897.0
244.3182         861.0
244.8864         806.0
245.4545         796.0
246.0227         780.0
246.5909         773.0
247.1591         767.0
247.7273         764.0
248.2955         761.0
248.8636         753.0
249.4318         750.0
```

8.19 HF20QWVD

```
.true.     : LERR6 error flag
.true.     : LERR12 error flag
.false.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.           : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.           : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.    : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
20.         : Frequency in MHz
20.        : Antenna height in m
8          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1          : Polarization (0=HOR, 1=VER)
0.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.         : Antenna elevation angle in deg (this value is ignored for OMNI and USRDEF antenna)
0            : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.         : Horizontal beamwidth in deg (used for clutter calcs)
0.         : Pulse length in microseconds (used for clutter calcs)
0.         : Transmitter power in kW (used for clutter calcs)
0.         : System losses in dB (used for clutter calcs)
0.         : Noise figure in dB (used for clutter calcs)
0.         : Minimum output height in m
1000.       : Maximum output height in m
100.        : Maximum output range in km
20         : Number of output height points
1          : Number of output range points
0            : Number of receiver heights relative to ground
0          : Extrapolation flag
0.         : Surface absolute humidity in g/m3
0.         : Surface air temperature in degrees
0.         : Gaseous absorption attenuation rate in dB/km
0            : Number of wind speeds/ranges specified
1          : Number of refractivity profiles
2          : Number of levels in refractivity profiles
0.         : Range of first refractivity profiles in km
```

```
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.20 HF20RF

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
20.        : Frequency in MHz
20.       : Antenna height in m
8         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1000.      : Maximum output height in m
100.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
1          : Number of wind speeds/ranges specified
10., 0.   : Wind speed (m/s), Range(km)
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.21 HF30.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
30.        : Frequency in MHz
10.       : Antenna height in m
```

```
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1000.      : Maximum output height in m
100.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.22 HIBW.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.     : Frequency in MHz
25.       : Antenna height in m
3         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
45.       : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
2000.     : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
```

```
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.23 HIEL.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.     : Frequency in MHz
25.       : Antenna height in m
2         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
1.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
10.       : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
20000.    : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in kkm
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.24 HIFREQ.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
20000.    : Frequency in MHz
25.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
```

```
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
200.      : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0           : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0           : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.25 HITRAN.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.     : Frequency in MHz
100.      : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1000.     : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0           : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0           : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
```

```
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.26 HORZ.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.     : Frequency in MHz
25.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
2000.     : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.27 HTFIND.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.     : Frequency in MHz
25.       : Antenna height in m
5         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
2.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
```

```
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
2000.     : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0           : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0           : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.28 LOBW.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.     : Frequency in MHz
25.       : Antenna height in m
2         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
.5        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
2000.     : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0           : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0           : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.29 LOEL.IN

```
.true.     : LERR6 error flag
.true.     : LERR12 error flag
.false.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.    : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.      : Frequency in MHz
25.        : Antenna height in m
2          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0          : Polarization (0=HOR, 1=VER)
1.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
-10.       : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.         : Horizontal beamwidth in deg (used for clutter calcs)
0.         : Pulse length in microseconds (used for clutter calcs)
0.         : Transmitter power in kW (used for clutter calcs)
0.         : System losses in dB (used for clutter calcs)
0.         : Noise figure in dB (used for clutter calcs)
0.         : Minimum output height in m
20000.     : Maximum output height in m
50.        : Maximum output range in km
20         : Number of output height points
1          : Number of output range points
0           : Number of receiver heights relative to ground
0          : Extrapolation flag
0.         : Surface absolute humidity in g/m3
0.         : Surface air temperature in degrees
0.         : Gaseous absorption attenuation rate in dB/km
0           : Number of wind speeds/ranges specified
1          : Number of refractivity profiles
2          : Number of levels in refractivity profiles
0.         : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.         : Wind direction in deg (only used for clutter calcs)
1          : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1          : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.   : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0          : Number of terrain range/height points
```

8.30 LOFREQ.IN

```
.true.     : LERR6 error flag
.true.     : LERR12 error flag
.false.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.    : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
100.       : Frequency in MHz
25.        : Antenna height in m
1          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0          : Polarization (0=HOR, 1=VER)
0.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.         : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.         : Horizontal beamwidth in deg (used for clutter calcs)
0.         : Pulse length in microseconds (used for clutter calcs)
0.         : Transmitter power in kW (used for clutter calcs)
```

```
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
5000.     : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.31 LOTRAN.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.     : Frequency in MHz
1.5       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
10000.    : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.32 MPRT.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
300.      : Frequency in MHz
800.      : Antenna height in m
2         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
0.5       : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
-2.5      : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1100.     : Maximum output height in m
60.       : Maximum output range in km
1         : Number of output height points
30        : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
7.5       : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 7, 7.5, 0.01   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
5         : Number of terrain range(km)/height points
0.      0
10.0    0
30.0    600
50.0    0
60.0    0
```

8.33 PERW.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.true.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
10.        : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
300.      : Frequency in MHz
10.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
180.      : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
```

```
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1000.      : Maximum output height in m
50.       : Maximum output range in km
1         : Number of output height points
20        : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
7.5       : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 7, 7.5, 0.01   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
11         : Number of terrain range(km)/height points
0.      0
18.750  0
20.312  210
21.875  320
23.4375 375
25.000  390
26.5625 375
28.125  320
31.250  90
32.8125 0
50.000  0
```

8.34 PVT.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
500.      : Frequency in MHz
10.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
180.      : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
2000.     : Maximum output height in m
10.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
7.5       : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
```

```
0           : Number of wind speeds/ranges specified
1          : Number of refractivity profiles
2          : Number of levels in refractivity profiles
0.         : Range of first refractivity profiles in km
0.      350.      : Height & M-unit value of ref. profile 1, level 1
1000.   468.      : Height & M-unit value of ref. profile 1, level 2
0.         : Wind direction in deg (only used for clutter calcs)
1          : Number of ground composition types
0., 7, 7.5, 0.01   : Range(km), ground type (integer), permittivity, conductivity
1          : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
17         : Number of terrain range(km)/height points
0.             625
3.170          476
6.340          347
9.510          239
12.690  151
15.870  83
19.040  35
22.220  7
25.000  0
27.780  7
30.960  35
34.130  83
37.310  151
40.490  239
43.660  347
46.830  476
50.000  625
```

8.35 RDLONGB.IN

```
.true.     : LERR6 error flag
.true.     : LERR12 error flag
.false.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.    : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
150.       : Frequency in MHz
100.       : Antenna height in m
1          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0          : Polarization (0=HOR, 1=VER)
1.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.         : Antenna elevation angle in deg (this value is ignored OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.         : Horizontal beamwidth in deg (used for clutter calcs)
0.         : Pulse length in microseconds (used for clutter calcs)
0.         : Transmitter power in kW (used for clutter calcs)
0.         : System losses in dB (used for clutter calcs)
0.         : Noise figure in dB (used for clutter calcs)
0.         : Minimum output height in m
1000.      : Maximum output height in m
100.       : Maximum output range in km
20         : Number of output height points
1          : Number of output range points
0           : Number of receiver heights relative to ground
0          : Extrapolation flag
0.         : Surface absolute humidity in g/m3
0.         : Surface air temperature in degrees
0.         : Gaseous absorption attenuation rate in dB/km
0           : Number of wind speeds/ranges specified
2          : Number of refractivity profiles
4          : Number of levels in refractivity profiles
0.         : Range of first refractivity profiles in km
0.     350.    : Height & M-unit value of ref. profile 1, level 1
0.     350.    : Height & M-unit value of ref. profile 1, level 2
0.     350.    : Height & M-unit value of ref. profile 1, level 3
1000.  468.   : Height & M-unit value of ref. profile 1, level 4
100.       : Range of second refractivity profiles in km
```

```
0.     339.   : Height & M-unit value of ref. profile 2, level 1
250.   368.5  : Height & M-unit value of ref. profile 2, level 2
300.   319.   : Height & M-unit value of ref. profile 2, level 3
1000.  401.6  : Height & M-unit value of ref. profile 2, level 4
0.        : Wind direction in deg (only used for clutter calcs)
6         : Number of ground composition types
0., 2, 0., 0.       : Range(km), ground type (integer), permittivity, conductivity
28.500, 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
64.800, 3, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
68.700, 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
74.100, 4, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
100.200, 0, 0., 0.  : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
167       : Number of terrain range/height points
 0.000      8       : Range & height of terrain point 1 in km
 0.300      8
 0.600      9
 0.900      9
 1.200     10
 1.500     11
 1.800     12
 2.100     13
 2.400     14
 2.700     15      : Range & height of terrain point 10 in km
 3.000     17
 3.300     19
 3.600     21
 3.900     23
 4.200     25
 4.500     27
 4.800     28
 5.100     30
 5.400     31
 5.700     31      : Range & height of terrain point 20 in km
 6.000     29
 6.300     23
 6.600     14
 6.900      9
 7.200      7
 7.500      7
 7.800      9
 8.100     11
 8.400     14
 8.700     13      : Range & height of terrain point 30 in km
 9.300     13
 9.600     12
 9.900     11
10.200      8
10.800      8
11.100      7
12.600      7
12.900      6
14.400      6
14.700      7      : Range & height of terrain point 40 in km
15.000      8
15.300      8
15.600      9
15.900     10
16.200     11
16.500     11
16.800     12
17.400     12
17.700     13
18.000     13      : Range & height of terrain point 50 in km
18.300     14
18.600     15
18.900     16
19.200     18
19.500     20
19.800     21
20.100     22
20.400     23
20.700     24
21.000     24      : Range & height of terrain point 60 in km
```

```
21.300     25
21.600     26
21.900     27
22.200     27
22.500     28
22.800     29
23.400     29
23.700     30
24.600     30
24.900     32      : Range & height of terrain point 70 in km
25.200     34
25.500     38
26.100     38
26.400     36
26.700     34
27.000     32
27.300     27
27.600     15
27.900      6
28.200      1      : Range & height of terrain point 80 in km
28.500      0
64.500      0
64.800      8
65.100     30
65.400     39
65.700     61
66.600     61
66.900     24
67.200     14
67.500     26      : Range & height of terrain point 90 in km
67.800     16
68.100      1
68.400      1
68.700      0
73.800      0
74.100      1
74.400      1
74.700     10
75.000      8
75.300     39      : Range & height of terrain point 100 in km
75.600     45
75.900     53
76.200     61
76.500     61
76.800     82
77.100     61
77.400     78
77.700     61
78.000    129
78.300     30      : Range & height of terrain point 110 in km
78.600     46
78.900    159
79.200    184
79.500    226
79.800    152
80.100    201
80.400    244
80.700    152
81.000    143
81.300     91      : Range & height of terrain point 120 in km
81.600    107
81.900    152
82.200    152
82.500    170
82.800    152
83.100     66
83.400     70
83.700    121
84.000    152
84.300    170      : Range & height of terrain point 130 in km
84.600    141
84.900    139
85.200    147
85.500    177
85.800    152
```

```
86.100     61
86.700     61
87.000     70
87.300     44
87.600     11      : Range & height of terrain point 140 in km
87.900      1
89.400      1
89.700     61
90.000     84
90.300    152
90.600    152
90.900    101
91.200     40
91.500     15
91.800     20      : Range & height of terrain point 150 in km
92.100      2
92.400     10
92.700      4
93.000      1
93.300      1
93.600      0
93.900      1
96.300      1
96.600      0
96.900      1      : Range & height of terrain point 160 in km
97.500      1
97.800      2
98.100      3
99.300      3
99.600      2
99.900      2
100.200      1     : Range & height of terrain point 167 in km
```

8.36 RNGDEP.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
3000.     : Frequency in MHz
25.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
5.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
2000.     : Maximum output height in m
250.      : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
2         : Number of refractivity profiles
4         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.    330.    : Height & M-unit value of ref. profile 1, level 1
100.  342.5   : Height & M-unit value of ref. profile 1, level 2
```

```
230.  312.5   : Height & M-unit value of ref. profile 1, level 3
2000. 517.8   : Height & M-unit value of ref. profile 1, level 4
250.      : Range of second refractivity profiles in km
0.    330.    : Height & M-unit value of ref. profile 2, level 1
600.  405.    : Height & M-unit value of ref. profile 2, level 2
730.  375.    : Height & M-unit value of ref. profile 2, level 3
2000. 522.3   : Height & M-unit value of ref. profile 2, level 4
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range(km)/height points
```

8.37 SBDUCT.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
3000.     : Frequency in MHz
25.       : Antenna height in m
2         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
5.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
5000.     : Maximum output height in m
200.      : Maximum output range in m
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
4         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      339.0       : Height & M-unit value of ref. profile 1, level 1
250.    368.5       : Height & M-unit value of ref. profile 1, level 2
300.    319.0       : Height & M-unit value of ref. profile 1, level 3
1000.   401.6       : Height & M-unit value of ref. profile 1, level 4
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.38 SBDUCTRF.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
```

```
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.    : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
3000.      : Frequency in MHz
25.        : Antenna height in m
2          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1          : Polarization (0=HOR, 1=VER)
5.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.         : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.         : Horizontal beamwidth in deg (used for clutter calcs)
0.         : Pulse length in microseconds (used for clutter calcs)
0.         : Transmitter power in kW (used for clutter calcs)
0.         : System losses in dB (used for clutter calcs)
0.         : Noise figure in dB (used for clutter calcs)
0.         : Minimum output height in m
1000.      : Maximum output height in m
200.       : Maximum output range in km
20         : Number of output height points
1          : Number of output range points
0           : Number of receiver heights relative to ground
0          : Extrapolation flag
0.         : Surface absolute humidity in g/m3
0.         : Surface air temperature in degrees
0.         : Gaseous absorption attenuation rate in dB/km
1           : Number of wind speeds/ranges specified
10., 0.    : Wind speed (m/s), Range(km)
1          : Number of refractivity profiles
4          : Number of levels in refractivity profiles
0.         : Range of first refractivity profiles in km
0.      339.0       : Height & M-unit value of ref. profile 1, level 1
250.    368.5       : Height & M-unit value of ref. profile 1, level 2
300.    319.0       : Height & M-unit value of ref. profile 1, level 3
1000.   401.6       : Height & M-unit value of ref. profile 1, level 4
0.         : Wind direction in deg (only used for clutter calcs)
1          : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1          : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.   : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0          : Number of terrain range/height points
```

8.39 SINEX.IN

```
.true.     : LERR6 error flag
.true.     : LERR12 error flag
.false.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.    : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.      : Frequency in MHz
25.        : Antenna height in m
3          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0          : Polarization (0=HOR, 1=VER)
1.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.         : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.         : Horizontal beamwidth in deg (used for clutter calcs)
0.         : Pulse length in microseconds (used for clutter calcs)
0.         : Transmitter power in kW (used for clutter calcs)
0.         : System losses in dB (used for clutter calcs)
0.         : Noise figure in dB (used for clutter calcs)
0.         : Minimum output height in m
2000.      : Maximum output height in m
50.0       : Maximum output range in km
20         : Number of output height points
1          : Number of output range points
```

```
0           : Number of receiver heights relative to ground
0          : Extrapolation flag
0.         : Surface absolute humidity in g/m3
0.         : Surface air temperature in degrees
0.         : Gaseous absorption attenuation rate in dB/km
0           : Number of wind speeds/ranges specified
1          : Number of refractivity profiles
2          : Number of levels in refractivity profiles
0.         : Range of first refractivity profiles in km
0.       350.       : Height & M-unit value of ref. profile 1, level 1
1000.    468.       : Height & M-unit value of ref. profile 1, level 2
0.         : Wind direction in deg (only used for clutter calcs)
1          : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1          : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.   : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0          : Number of terrain range/height points
```

8.40 TROPOS.IN

```
.true.     : LERR6 error flag
.true.     : LERR12 error flag
.false.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.true.     : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
100.       : Frequency in MHz
25.        : Antenna height in m
1          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0          : Polarization (0=HOR, 1=VER)
0.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.         : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0           : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.         : Horizontal beamwidth in deg (used for clutter calcs)
0.         : Pulse length in microseconds (used for clutter calcs)
0.         : Transmitter power in kW (used for clutter calcs)
0.         : System losses in dB (used for clutter calcs)
0.         : Noise figure in dB (used for clutter calcs)
0.         : Minimum output height in m
2000.      : Maximum output height in m
200.       : Maximum output range in m
20         : Number of output height points
1          : Number of output range points
0           : Number of receiver heights relative to ground
0          : Extrapolation flag
0.         : Surface absolute humidity in g/m3
0.         : Surface air temperature in degrees
0.         : Gaseous absorption attenuation rate in dB/km
0           : Number of wind speeds/ranges specified
1          : Number of refractivity profiles
2          : Number of levels in refractivity profiles
0.         : Range of first refractivity profiles in km
0.       350.       : Height & M-unit value of ref. profile 1, level 1
1000.    468.       : Height & M-unit value of ref. profile 1, level 2
0.         : Wind direction in deg (only used for clutter calcs)
1          : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1          : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.   : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0          : Number of terrain range/height points
```

8.41 TROPOT.IN

```
.true.     : LERR6 error flag
.true.     : LERR12 error flag
.false.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
```

```
0.          : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.true.     : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
100.       : Frequency in MHz
25.        : Antenna height in m
1          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0          : Polarization (0=HOR, 1=VER)
0.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.         : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0            : Number of cut-back angles and factors (used for specific height-finder antenna)
0.        : Antenna gain in dBi  (used for clutter calcs)
0.         : Horizontal beamwidth in deg (used for clutter calcs)
0.         : Pulse length in microseconds (used for clutter calcs)
0.         : Transmitter power in kW (used for clutter calcs)
0.         : System losses in dB (used for clutter calcs)
0.         : Noise figure in dB (used for clutter calcs)
0.         : Minimum output height in m
2000.      : Maximum output height in m
200.       : Maximum output range in m
20         : Number of output height points
1          : Number of output range points
0            : Number of receiver heights relative to ground
0          : Extrapolation flag
0.         : Surface absolute humidity in g/m3
0.         : Surface air temperature in degrees
0.         : Gaseous absorption attenuation rate in dB/km
0            : Number of wind speeds/ranges specified
1          : Number of refractivity profiles
2          : Number of levels in refractivity profiles
0.         : Range of first refractivity profiles in km
0.       350.       : Height & M-unit value of ref. profile 1, level 1
1000.    468.       : Height & M-unit value of ref. profile 1, level 2
0.         : Wind direction in deg (only used for clutter calcs)
6          : Number of ground composition types
0., 2, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
28.500, 0, 0., 0.
64.800, 3, 0., 0.
68.700, 0, 0., 0.
74.100, 4, 0., 0.
100.200, 0, 0., 0.
1          : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
169        : Number of terrain range/height points
 0.000      8      : Range(km) & height(m) of terrain point 1
 0.300      8
 0.600      9
 0.900      9
 1.200     10
 1.500     11
 1.800     12
 2.100     13
 2.400     14
 2.700     15      : Range(km) & height(m) of terrain point 10
 3.000     17
 3.300     19
 3.600     21
 3.900     23
 4.200     25
 4.500     27
 4.800     28
 5.100     30
 5.400     31
 5.700     31      : Range(km) & height(m) of terrain point 20
 6.000     29
 6.300     23
 6.600     14
 6.900      9
 7.200      7
 7.500      7
 7.800      9
 8.100     11
 8.400     14
```

```
  8.700     13      : Range(km) & height(m) of terrain point 30
  9.300     13
  9.600     12
  9.900     11
 10.200      8
 10.800      8
 11.100      7
 12.600      7
 12.900      6
 14.400      6
 14.700      7      : Range(km) & height(m) of terrain point 40
 15.000      8
 15.300      8
 15.600      9
 15.900     10
 16.200     11
 16.500     11
 16.800     12
 17.400     12
 17.700     13
 18.000     13      : Range(km) & height(m) of terrain point 50
 18.300     14
 18.600     15
 18.900     16
 19.200     18
 19.500     20
 19.800     21
 20.100     22
 20.400     23
 20.700     24
 21.000     24      : Range(km) & height(m) of terrain point 60
 21.300     25
 21.600     26
 21.900     27
 22.200     27
 22.500     28
 22.800     29
 23.400     29
 23.700     30
 24.600     30
 24.900     32      : Range(km) & height(m) of terrain point 70
 25.200     34
 25.500     38
 26.100     38
 26.400     36
 26.700     34
 27.000     32
 27.300     27
 27.600     15
 27.900      6
 28.200      1      : Range(km) & height(m) of terrain point 80
 28.500      0
 64.500      0
 64.800      8
 65.100     30
 65.400     39
 65.700     61
 66.600     61
 66.900     24
 67.200     14
 67.500     26      : Range(km) & height(m) of terrain point 90
 67.800     16
 68.100      1
 68.400      1
 68.700      0
 73.800      0
 74.100      1
 74.400      1
 74.700     10
 75.000      8
 75.300     39      : Range(km) & height(m) of terrain point 100
 75.600     45
 75.900     53
 76.200     61
 76.500     61
```

```
76.800     82
77.100     61
77.400     78
77.700     61
78.000    129
78.300     30      : Range(km) & height(m) of terrain point 110
78.600     46
78.900    159
79.200    184
79.500    226
79.800    152
80.100    201
80.400    244
80.700    152
81.000    143
81.300     91      : Range(km) & height(m) of terrain point 120
81.600    107
81.900    152
82.200    152
82.500    170
82.800    152
83.100     66
83.400     70
83.700    121
84.000    152
84.300    170      : Range(km) & height(m) of terrain point 130
84.600    141
84.900    139
85.200    147
85.500    177
85.800    152
86.100     61
86.700     61
87.000     70
87.300     44
87.600     11      : Range(km) & height(m) of terrain point 140
87.900      1
89.400      1
89.700     61
90.000     84
90.300    152
90.600    152
90.900    101
91.200     40
91.500     15
91.800     20      : Range(km) & height(m) of terrain point 150
92.100      2
92.400     10
92.700      4
93.000      1
93.300      1
93.600      0
93.900      1
96.300      1
96.600      0
96.900      1      : Range(km) & height(m) of terrain point 160
97.500      1
97.800      2
98.100      3
99.300      3
99.600      2
99.900      2
100.200      1
100.200     0.
200.000     0.  : Range(km) & height(m) of terrain point 167
```

8.42 USERDEFA

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
```

```
1.          : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
900.      : Frequency in MHz
6.        : Antenna height in m
7         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
2.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
54          : Number of angle/factor pairs (used for antenna types 6 and 7)
-17            0.017
-16            0.044
-15            0.080
-14            0.126
-13            0.182
-12            0.245
-11            0.316
-10            0.389
-9             0.479
-8             0.556
-7             0.631
-6             0.716
-5             0.785
-4             0.861
-3             0.912
-2             0.966
-1             0.998
0              1.000
1              1.000
2              0.966
3              0.902
4              0.822
5              0.742
6              0.646
7              0.569
8              0.501
9              0.452
10             0.422
11             0.402
12             0.389
13             0.375
14             0.359
15             0.339
16             0.305
17             0.276
18             0.245
19             0.221
20             0.210
21             0.199
22             0.190
23             0.180
24             0.164
25             0.148
26             0.130
27             0.110
28             0.095
29             0.077
30             0.070
31             0.065
32             0.058
33             0.050
34             0.039
35             0.031
36             0.025
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
3000.     : Maximum output height in m
300.      : Maximum output range in km
20        : Number of output height points
```

```
1          : Number of output range points
0            : Number of receiver heights relative to ground
0          : Extrapolation flag
0.         : Surface absolute humidity in g/m3
0.         : Surface air temperature in degrees
0.         : Gaseous absorption attenuation rate in dB/km
0            : Number of wind speeds/ranges specified
1          : Number of refractivity profiles
4          : Number of levels in refractivity profiles
0.         : Range of first refractivity profiles in km
0.      339.0       : Height & M-unit value of ref. profile 1, level 1
250.    368.5       : Height & M-unit value of ref. profile 1, level 2
300.    319.0       : Height & M-unit value of ref. profile 1, level 3
1000.   401.6       : Height & M-unit value of ref. profile 1, level 4
0.         : Wind direction in deg (only used for clutter calcs)
1          : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1          : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0          : Number of terrain range/height points
```

8.43 USERHF.IN

```
.true.     : LERR6 error flag
.true.     : LERR12 error flag
.false.    : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.           : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.           : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.    : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.     : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.    : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.      : Frequency in MHz
25.        : Antenna height in m
6          : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0          : Polarization (0=HOR, 1=VER)
1.         : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.         : Antenna elevation angle in deg (this value is ignored OMNI,USRDEF, and QWVD antennas)
10           : Number of angle/factor pairs (used for antenna types 6 and 7)
1.0  0.9
1.5  0.8
2.0  0.7
2.5  0.6
3.0  0.5
3.5  0.4
4.0  0.3
4.5  0.2
5.0  0.1
5.5  0.0
0.        : Antenna gain in dBi  (used for clutter calcs)
0.         : Horizontal beamwidth in deg (used for clutter calcs)
0.         : Pulse length in microseconds (used for clutter calcs)
0.         : Transmitter power in kW (used for clutter calcs)
0.         : System losses in dB (used for clutter calcs)
0.         : Noise figure in dB (used for clutter calcs)
0.         : Minimum output height in m
2000.      : Maximum output height in m
50.0       : Maximum output range in km
20         : Number of output height points
1          : Number of output range points
0            : Number of receiver heights relative to ground
0          : Extrapolation flag
0.         : Surface absolute humidity in g/m3
0.         : Surface air temperature in degrees
0.         : Gaseous absorption attenuation rate in dB/km
0            : Number of wind speeds/ranges specified
1          : Number of refractivity profiles
2          : Number of levels in refractivity profiles
0.         : Range of first refractivity profiles in km
0.       350.       : Height & M-unit value of ref. profile 1, level 1
1000.    468.       : Height & M-unit value of ref. profile 1, level 2
0.         : Wind direction in deg (only used for clutter calcs)
1          : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
```

```
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.44 VERT.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.     : Frequency in MHz
25.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
0.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of angle/factor pairs (used for antenna types 6 and 7)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
2000.     : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.       350.       : Height & M-unit value of ref. profile 1, level 1
1000.    468.       : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.45 VERTMIX.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
100.      : Frequency in MHz
10.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
1.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of angle/factor pairs (used for antenna types 6 and 7)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
```

```
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1000.     : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.       350.       : Height & M-unit value of ref. profile 1, level 1
1000.    468.       : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
2         : Number of ground composition types
0., 4, 0., 0.       : Range(km), ground type (integer), permittivity, conductivity
25.0, 0, 0., 0.     : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
2         : Number of terrain range/height points
0.        0.    : Range(km) & height(m) of terrain point 1
50.       0.    : Range(km) & height(m) of terrain point 2
```

8.46 VERTSEA.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
100.      : Frequency in MHz
25.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
1.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1000.     : Maximum output height in m
300.      : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
4         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.      339.0       : Height & M-unit value of ref. profile 1, level 1
250.    368.5       : Height & M-unit value of ref. profile 1, level 2
300.    319.0       : Height & M-unit value of ref. profile 1, level 3
1000.   401.6       : Height & M-unit value of ref. profile 1, level 4
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
```

```
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
0         : Number of terrain range/height points
```

8.47 VERTUSRD.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
100.      : Frequency in MHz
10.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
1         : Polarization (0=HOR, 1=VER)
1.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
0.       : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1000.     : Maximum output height in m
50.       : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.       350.       : Height & M-unit value of ref. profile 1, level 1
1000.    468.       : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 7, 3., 6.e-4   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
2         : Number of terrain range/height points
0.        0.    : Range(km) & height(m) of terrain point 1
50.       0.    : Range(km) & height(m) of terrain point 2
```

8.48 WEDGE.IN

```
.true.    : LERR6 error flag
.true.    : LERR12 error flag
.false.   : Perform PE calcs only? ('.true.' = yes, '.false.' = no)
0.         : Maximum PE calculation angle in degrees (required if using PE calcs only, ignored
otherwise)
1.         : PE range step multiplier (required if using PE calcs only, ignored otherwise)
.false.   : Troposcatter flag: '.false.'=no troposcatter, '.true.'=troposcatter
.false.    : Clutter flag: '.false.'=no clutter, '.true.'=clutter calcs
.false.   : Propagation angle/factor flag: '.false.'=don't compute; '.true.'= compute
1000.     : Frequency in MHz
25.       : Antenna height in m
1         : Antenna type (1=OMNI,2=GAUSS,3=SINC(X),4=COSEC2,5=HTFIND,6=USRHTFIND,7=USRDEF,8=QWVD)
0         : Polarization (0=HOR, 1=VER)
1.        : Beamwidth in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0.        : Antenna elevation angle in deg (this value is ignored for OMNI,USRDEF, and QWVD antennas)
0          : Number of cut-back angles and factors (used for specific height-finder antenna)
```

```
0.        : Antenna gain in dBi  (used for clutter calcs)
0.        : Horizontal beamwidth in deg (used for clutter calcs)
0.        : Pulse length in microseconds (used for clutter calcs)
0.        : Transmitter power in kW (used for clutter calcs)
0.        : System losses in dB (used for clutter calcs)
0.        : Noise figure in dB (used for clutter calcs)
0.        : Minimum output height in m
1000.     : Maximum output height in m
100.      : Maximum output range in km
20        : Number of output height points
1         : Number of output range points
0          : Number of receiver heights relative to ground
0         : Extrapolation flag
0.        : Surface absolute humidity in g/m3
0.        : Surface air temperature in degrees
0.        : Gaseous absorption attenuation rate in dB/km
0          : Number of wind speeds/ranges specified
1         : Number of refractivity profiles
2         : Number of levels in refractivity profiles
0.        : Range of first refractivity profiles in km
0.       350.       : Height & M-unit value of ref. profile 1, level 1
1000.    468.       : Height & M-unit value of ref. profile 1, level 2
0.        : Wind direction in deg (only used for clutter calcs)
1         : Number of ground composition types
0., 0, 0., 0.   : Range(km), ground type (integer), permittivity, conductivity
1         : Number of GAMMAC & GAMRNG pairs (used for clutter calcs-MUST be > 0 if terrain is specified)
-10., 0.  : GAMMAC (dB), GAMRNG (km) - 1st pair (remove line if # of GAMMAC/GAMRNG pairs is 0)
5         : Number of terrain range/height points
0.           0.    : Range(km) & height(m) of terrain point 1
45.0       0.    : Range(km) & height(m) of terrain point 2
50.0       200.  : Range(km) & height(m) of terrain point 3
55.0       0.    : Range(km) & height(m) of terrain point 4
100.0      0.    : Range(km) & height(m) of terrain point 5
```